COMPREHENSIVE EXPLANATIONS OF THE EFFICIENCY GAP AND THE INTERSECTION OF THE EFFICIENTY GAP AND CLIMATE CHANGE LITERATURES

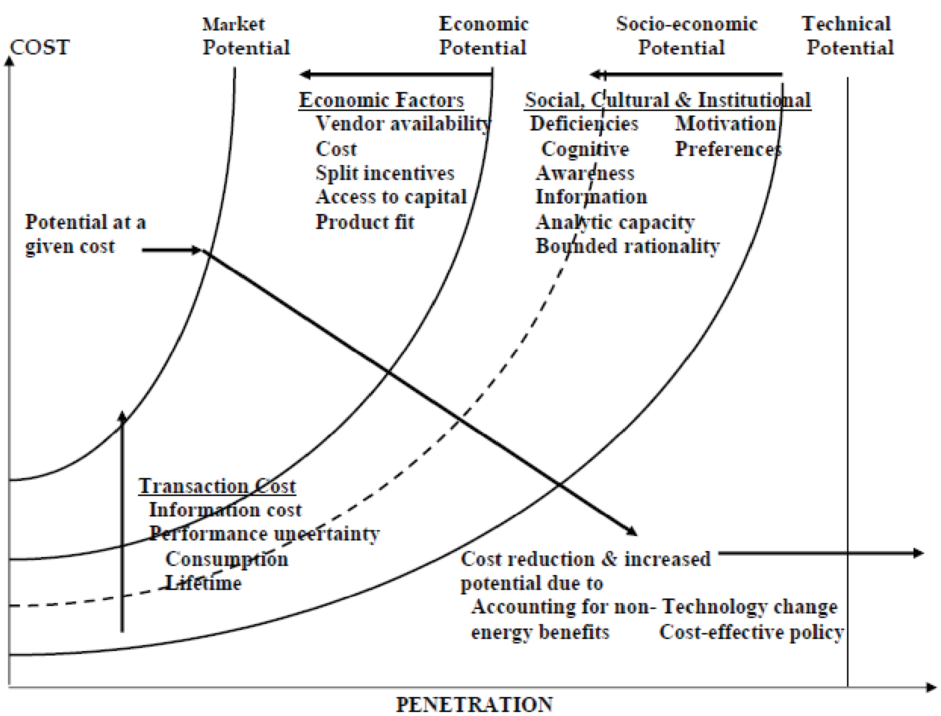
ENERGY EFFICIENCY PERFORMANCE STANDARDS: The Cornerstone of Consumer-Friendly Energy Policy, October 2013

This section presents a comprehensive analytic framework that explains the energy efficiency gap by examining several frameworks that have been developed over the past two decades. These frameworks rest upon a strong foundation of empirical analysis that has been developed over more than a quarter of a century and strengthened considerably in the past decade. After developing the overall framework, we review the recent empirical evidence that supports key pieces of the framework.

A. THE LBL FRAMEWORK

An analytic framework that rests on a technology investment approach was offered by analysts at Lawrence Berkeley National Laboratory (LBL). As shown in in Exhibit II-1, one can use a technology investment framework to assess the factors that cause investment in energy efficiency to fall well short of the technical potential.

EXHIBIT II-1: PENETRATION OF MITIGATION TECHNOLOGIES: A CONCEPTUAL FRAMEWORK



Source: **Jayant Sathaye and Scott Murtishaw, *Market Failures, Consumer Preferences, and Transaction Costs in Energy Efficiency Purchase Decisions* (California Energy Commission, November 2004), p. 11.**

The LBL study identified broad categories of market imperfections, barriers, and obstacles that are important in determining the level of investments – economic, transaction cost, and social cultural and institutional. The analysis emphasizes the important role that policy can play in determining where the market will settle. Thus, there are six broad categories of factors that must be incorporated into the analysis of the level of investment in energy saving technologies. Market performance is influenced by:

- behavioral factors (social, cultural & institutional)
- economic factors
- transaction costs
- externalities (non-energy costs)
- technological change
- public policy

Exhibit II-2 summarizes an earlier 1996 paper prepared by other analysts at the LBL.[1] Exhibit A-II-2 provides citations. The analysis was framed in terms of the role of policy intervention to promote efficiency as states restructured the electricity market. The paper "focuses on understanding to what extent some form of future intervention may be warranted and how we might judge the success of particular interventions."[2] Restructuring did not spread throughout the utility industry and in the past few years, reliance on interventions in the market to increase efficiency and renewables has grown, even in the deregulated states.[3] The growth of market interventions is consistent with the conclusions in the LBL paper.

> We conclude that there are compelling justifications for future energy-efficiency policies. Nevertheless, in order to succeed, they must be based on a sound understanding of the market problems they seek to correct and a realistic assessment of their likely efficacy.[4]

EXHIBIT II-2: MARKET BARRIERS TO ENERGY EFFICIENCY

Barriers[1]	**Market Failures**	**Transaction Cost[2]**	**Behavioral factors[16]**
Misplaced incentives	Externalities	Sunk costs[3]	Custom[17]
Agency[4]	Mis-pricing[20]	Lifetime[5]	Values[18] & Commitment[19]
Capital Illiquidity[8]	Public Goods[22]	Risk[6] & Uncertainty[7]	Social group & status[21]
Bundling	Basic research[23]	Asymmetric Info.[9]	Psychological Prospect[24]
Multi-attribute	Information	Imperfect Info.[10]	Ability to process info[27]
Gold Plating[11]	(Learning by Doing)[25]	Availability	Bounded rationality[26]
Inseparability[13]	Imperfect Competition/	Cost[12]	
Regulation	Market Power[28]	Accuracy	
Price Distortion[14]			
Chain of Barriers			
Disaggregated Mkt.[15]			

William H. Golove and Joseph H. Eto, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency.* For citations, see Appendix A, Exhibit A-II-2

As shown in Exhibit II-2, the Golove and Eto paper identified four broad categories of factors that inhibited investments in energy efficiency – barriers, transactions costs, market failures, and

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[1] Golove and Eto, 1996.
[2] Golov and Eto, 1996, p. iv.
[3] There has recently been a dramatic re-commitment to publicly-sponsored energy efficiency and a substantial increase in allocated resources, Sanstad, Hanemann and Auffhammer, 2006, p. 6-5.
[4] Golove and Ito, 1996, p. x.

behavioral (noneconomic) factors. It identifies about two dozen specific factors spread roughly equally across these four categories. A key aspect of the analysis is to identify each of the categories as coming from a different tradition in the economic literature. The barriers category is made up of market structural factors. The market failure category is made up of externalities and imperfect competition. The LBL paper bases a substantial part of its argument on a transaction cost perspective as a critique of neo-classical economics.

> Neo-classical economics generally relies on the assumption of frictionless transactions in which no costs are associated with the transaction itself. In other words, the cost of activities such as collecting and analyzing information; negotiating with potential suppliers, partners and customers; and risk are assumed to be nonexistent or insignificant. This assumption has been increasingly challenged in recent years. The insights developed through these challenges represent an important way to evaluate aspects of various market failures (especially those associated with imperfect information).[5]

Starting from the observation that "transaction costs are not insignificant but, in fact, constitute a primary explanation for the particular form taken by many economic institutions and contractual relations"[6] the LBL paper identifies such costs and information as a critical issue, pointing out that "the key issue surrounding information is not its public goods character, but rather its asymmetric distribution combined with the tendency of those who have it to use it opportunistically."[7] Indeed, information plays a very large role in the analysis, entering in six different ways. In addition to the public goods and asymmetry concerns, the paper identifies four other ways information can create a barrier to efficiency –"(1) the lack of information, (2) the cost of information, (3) the accuracy of information, and (4) the ability to use or act upon information."[8]

C. THE RFF FRAMEWORK

A more recent paper from Resources for the Future (RFF), entitled *Energy Efficiency Economics and Policy,* addresses exactly the same issues as the earlier LBL paper – the debate over the efficiency gap observed in energy markets. The authors of the RFF paper characterize the efficiency gap debate as follows:

> Much of the literature on energy efficiency focuses on elucidating the potential rationales for policy intervention and evaluating the effectiveness and cost of such interventions in practice. Within this literature there is a long-standing debate surrounding the commonly cited "energy efficiency gap..." Within the investment framework… the energy efficiency gap takes the form of under investment in energy efficiency relative to a description of the socially optimal level of energy efficiency. Such under investment is also sometimes described as an observed rate or probability of adoption of energy-efficient technologies that is "too slow."[9]

The RFF framework is summarized in Exhibit II-3. Exhibit A-II-3 provides citations. Exhibit II-3 is taken from the RFF paper, but extended in two ways. In the market failure category, it shows the distinction between the structural and societal levels suggested by the paper. It also includes a few

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[5] Golove and Eto, p. 22.
[6] Golove and Eto, p. 23.
[7] Golove and Eto, p. 23.
[8] Golove and Eto, p. 20.
[9] Gillingham, Newell and Palmer, p. 7.

more specific failures that were discussed in the text, but not included in the original table. There are about a dozen specific market failures spread across these categories.

EXHIBIT II-3: MARKET AND BEHAVIORAL FACTORS RELEVANT TO ENERGY EFFICIENCY

Societal Failures	***Structural Failures***	***Potential Behavioral Failures***[11]
Energy Market Failures	Capital Market Failures	Prospect theory[12]
Environmental Externalities[1]	Liquidity constraints[5]	Bounded rationality[13]
Energy Security	Information problems[6]	Heuristic decision making[14]
Innovation market failures	Lack of information[7]	Information[15]
Research and development spillovers[2]	Asymmetric info. >	
Learning-by-doing spillovers[3]	Adverse selection[8]	
Learning-by-using[4]	Principal-agent problems[9]	
	Average-cost electricity pricing[10]	

Source: Kenneth Gillingham, Richard G. Newell, and Karen Palmer, *Energy Efficiency Economics and Policy* (Resources for the Future, April 2009). For Citations, see Appendix A, Exhibit A-II-3

The RFF paper suggests three broad categories of market failures – the individual, the interaction between economic agents and the fit between economic agents and society. We refer to these three levels as the behavioral, the market structural and the societal levels. In the present context, we consider behavioral failures to represent consumer behavior that is inconsistent with utility maximization, or in the current context, energy service cost-minimization. In contrast, market failure analysis is distinct in presupposing individual rationality and focusing on the conditions surrounding interactions among economic agents and society.[10] The societal level market failures are closest to what the traditional sources of the economic literature refers to as market failure. These are primarily externalities and public goods. These were also considered market failures in the LBL framework. The LBL barriers and transaction costs fit in the category of interactions between economic agents, as would imperfect competition.

One obvious point is that, once again, information problems occur in all categories of the RFF analysis, with several manifestations in each. Information can be a problem at the societal level since it can be considered a public good that is not produced because the authors of the information cannot capture the social value of information. It is a structural problem because, where it is lacking, even capable, well-motivated individuals cannot make efficient choices. Finally, where it is asymmetric, individuals can take advantage of the less informed to produce outcomes that are not efficient. It is a problem at the behavioral level where individuals lack the ability to gather and process information.

D. OTHER RECENT COMPREHENSIVE EFFICIENCY GAP FRAMEWORKS

In the past few years, several comprehensive reviews have been offered that attempt to depict the many diverse factors that underlie the efficiency gap.

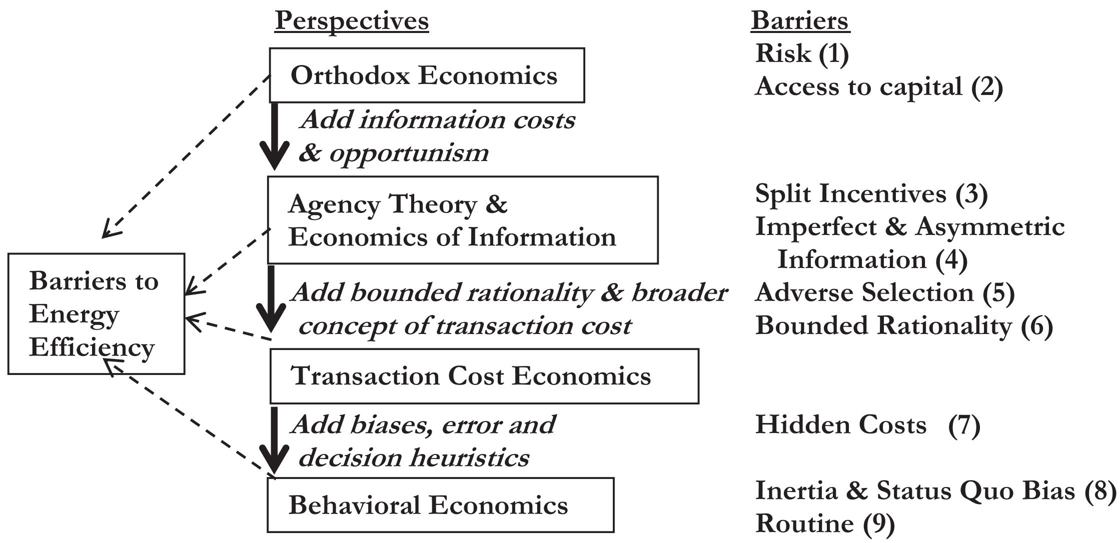
The United Nations Industrial Development Organization

Exhibit II-4 summarizes a recent comprehensive review of the causes of the efficiency gap in industrial sectors across the globe. Exhibit A-II-4 provides citations. It is based on a conceptualization and analysis prepared for the United Nations Industrial Organization by analysts at universities in the

[10] Id., p. 8.

United Kingdom (hereafter UNIDO). It is based on a review of over 160 studies of barriers to energy efficiency in industrial enterprises.

EXHIBIT II-4: BARRIERS TO INDUSTRIAL ENERGY EFFICIENCY



Steve Sorrell, Alexandra Mallett & Sheridan Nye. *Barriers to industrial energy efficiency, A literature review,* United Nations Industrial Development Organization, Vienna, 2011, Figure 3.1 & Section 3. For citations, see Appendix A, Exhibit A-II-4.

It can be argued that the analysis of industrial sectors provides the most compelling evidence that an energy efficiency gap exists, since these are contexts in which the incentive to adopt economically rational technologies should be strong, if not pure, and the knowledge and ability to evaluate alternatives should be greater than society at large. Moreover, since energy is a cost of doing business, records and data should be superior to the residential sector, so evaluation and calculation should be better. In spite of these factors pointing toward economic rationality, and notwithstanding assumptions of motivation and capability, these authors find solid empirical evidence that the efficiency gap exists.

As was the case in the LBL analysis, the UNIDO analysis identified a school of economic thought that can be closely associated with each of the categories of market barriers and imperfections. The broad categories in the UNIDO analysis match up well with the perspectives offered by LBL and RFF with the addition of the category of externalities. The UNIDO document offers six broad types of barriers, with two dozen subtypes.

Exhibit II-7 lists the full array of market failures, barriers and imperfections that cause the underinvestment in energy saving technologies derived from the conceptual discussion above. It identifies the individual problems that the recent empirical literature observed in the energy market. Citations are provided in Appendix A, Exhibit A-II-7.

Embedded in the literature reviews for each of the recent studies are citations to earlier empirical studies that provide the context for the more recent research. All of the failures, barriers and imperfections have been supported in the empirical literature, which is why they have been recognized in the conceptual frameworks. We will not review all the many studies that support each problem. Here we summarize several important, repeated broad themes.

EXHIBIT II-7: RECENT EMPIRICAL EVIDENCE ON MARKET FAILURES, BARRIERS AND IMPERFECTIONS

TRADITIONAL ECONOMICS & INDUSTRIAL ORGANIZATION

Externalities
- Public goods[1] & Bads[2]
- Basic research
- Network effects
- Information as a public good
- Learning-by-doing & Using[9]

Industry Structure
- Imperfect Competition
  - Concentration[13]
  - Barriers to entry
  - Scale[18]
  - Switching costs[20]
- Technology[23]
  - R&D
  - Investment[25]
- Marketing
  - Bundling: Multi-attribute[26]
  - Substitutes[27]
- Cost-Price
  - Limit impact of price[29]
    - Fragmented Mkt.[30]
    - Limited payback[31]

Regulation
- Price[34]
  - Infrequent
  - Aggregate, Avg.-cost[35]
- Lack of commitment[36]

NEW INSTITUTIONAL ECONOMICS

Endemic Imperfections
- Asymmetric Info[3].
- Agency[5]
- Adverse selection[6]
- Perverse incentives
- Lack of capital[10]

TRANSACTION COST
- Search and Information
- Imperfect info[14]
  - Availability[16]
  - Accuracy
  - Search cost[21]
- Bargaining
  - Risk & Uncertainty[24]
  - Liability
- Enforcement
- Sunk costs
- Hidden cost[28]

Political Power
- Power of incumbents to hinder alternatives
- Monopolistic structures and lack of competition
- Importance of institutional support for Alternatives[32]
- Inertia[33]

BEHAVIORAL ECONOMICS

Motivation & Values
- Non-economic[4]

Influence & Commitment
- Custom[7]
- Social group & status[8]

Perception
- Bounded Vision/Attention[11]
- Prospect[12]

Calculation.
- Bounded rationality[15]
- Limited ability to process info[17]
- Heuristic decision making[19]
- Discounting difficulty[22]

See Appendix A Exhibit A-II-7 for citations.

Positive Externalities

There is a very large literature on the externalities associated with energy consumption. Importantly, it goes well beyond the negative national security and environmental externalities, which are frequently noted in energy policy analysis. The macroeconomic effects of energy consumption and energy savings are important externalities of the efficiency gap.

There are two macroeconomic effects that have begun to receive a great deal of attention – multipliers and price effects. These will be discussed in greater length in the next section, as they belong in the cost benefit analysis as a substantial benefit. They can be briefly described as follows. Reducing energy consumption tends to reduce economic activities that have relatively small multipliers (especially when energy imports are involved as in the transportation sector) and increase economic activities that have large multipliers (including the direct effects of spending on technology and the indirect effect of increased household disposable income).

A second set of externalities that receives considerable attention is the effect of learning that can be stimulated by a performance standard that pushes firms to make investments they would not have made without the presence of the standard. This will be discussed in the next section, since it affects the cost side of the cost-benefit calculation.

Information and Behavior

Consumers and producers are poorly informed, influenced by social pressures and constrained in their ability to make the calculations necessary to arrive at objectively efficient decisions. Consumers and producers apply heuristics that reflect rationality that is bounded by factors like risk and loss aversion. Inattention to energy efficiency is rational, given the magnitude, variability and uncertainty of costs, as well as the multi-attribute nature of energy consuming durables. Consumers are influenced by social norms and advertising.

The product is a bundle of attributes in which other traits are important and energy costs are hidden costs. The resulting energy expenditures are important components of total household spending. Important benefits of energy consuming durables may be "shrouded" in the broader multi-attribute product.

Market Structure and Transaction Costs

Uncertainties about the nature of the market and the value and cost of technology and limitations of technological expertise and information play an important role, increasing the cost and raising the risk of adopting new technologies.

As a result of these factors, the marketplace yields a limited set of choices because producers and consumers operate under a number of constraints. Split incentives flowing from the agency problem are a frequently analyzed issue. When the purchaser of the energy consuming durables and the users are different people, inefficient choices result.

The market exhibits a high "implicit" discount rate, which we interpret as the result of the many barriers and imperfections that retard investment in efficiency enhancing technology. There are several aspects of the high discount rate that deserve separate attention. There is a low willingness to pay and a low elasticity of demand.

V. THE INTERSECTION OF THE EFFICIENTY GAP AND CLIMATE CHANGE LITERATURES

A. THE CENTRAL ECONOMIC DEBATE IN THE CLIMATE POLICY ARENA

A recent exchange in *Energy Economics* provides a direct link from the climate change debate to the central issue of the market imperfection/barrier framework. It was set up as a debate between William Nordhaus and Jon Weyant who offered contrasting points of view, with Roger Noll commenting.

Exhibit V-1 summarizes the market barriers and imperfections identified in the exchange between Nordhaus, Weyant and Noll. It sorts the specific barriers into six generic categories that we have identified in the literature of several sectors, including the energy sector. Sometimes the exception proves the rule.[11] That is the case when the exception is rare and demonstrates the robustness of the rule's underlying assumption. However, when the exceptions are numerous and important, they are more likely to consume the rule than prove it.[12]

EXHIBIT V-1: MARKET BARRIERS & IMPERFECTIONS: NORDHAUS, WEYANT AND NOLL

SOCIAL EXTERNALITIES
Sufficiently high & "right" price on the externality
Other externalities
Research & Development
- Non-profit
- Private Appropriability
  - Process innovation
  - Transparency of innovation
  - Institutional innovation

Network Effects
Global Connections

MARKET STRUCTURE
Large Scale
Oligopolistic structure
Regulation

ENDEMIC PROBLEMS
Asymetrric (Strategically Withheld) Information
Principle Agent problems
Lack of financing opportunities
Insufficient incentive to make optimal investment

POLITICAL
Incumbent incentives to delay
Political inability to sustain tax

TRANSACTION COSTS
Uncertainty
Risk
Information
- Lack
- Difficulty

BEHAVIORAL
Consumer Decision Making Limitations
- Knowledge
- Time
- Calculation

Nordaus' defense of what he calls the "price fundamentalism" approach to climate change analysis and policy making concedes a long list of exceptions to "price fundamentalism" that are seen as extremely important by a growing number of energy analysts.

> Getting the price of carbon right is fundamentally important for stimulating innovations in technologies to mitigate global warming. The major necessary condition for ensuring that climate friendly innovation occurs is that the price of carbon is sufficiently high…Under very limited conditions, setting carbon prices to reflect the damages from carbon emission is also a sufficient

[11] Wikipedia, "Scientific sense: A case may appear at first sight to be an exception to the rule. However, when the situation is examined more closely, it is observed that the rule does not apply to this case, and thus the rule is shown to be valid after all." http://en.wikipedia.org/wiki/Exception_that_proves_the_rule

[12] Wikipedia, The statement may also be an argument that the initial rule is flawed, and instead the exception should be the rule….: "Exception that was successful enough to create a new rule or prove the assumed rule was flawed". It could also be argued the rule simply changed." http://en.wikipedia.org/wiki/Exception_that_proves_the_rule

> condition for the appropriate innovation to be undertaken in market-oriented sectors. This conclusion, which I have labeled "price fundamentalism," must be qualified if the price is wrong and for those parts of research that are not profit-driven (particularly basic research), and when energy investments have particular burdens such as networking or large scale…
>
> If the environmental externality is mispriced, the marginal social return to green investment will be misaligned with those in normal industries…
>
> Technology policy may not optimally internalize the innovation spillovers. This may occur because appropriability differs across sectors and technologies and perhaps even within technologies. It is clear that appropriability is low for fundamental research. Some economists believe that appropriability is low for process (as opposed to product) innovations, transparent (as opposed to easily hidden) innovations, administrative or institutional (as opposed to production) innovations, and networked (as opposed to stand-alone) innovations…
>
> A final important qualification is that this analysis applies primarily to research that is profit-oriented… One issue involves sectors that have a substantial component of not-for-profit research…A second important question is where government should draw the line between areas that are viewed as appropriate for not-for-profit support and those that are governed by the market...
>
> Most other possible qualifications turn out to be specific applications of one of the first three.
>
> [Qualification 1]… Energy production has many other externalities… Energy technology has a particularly global dimension.
>
> [Qualification 2]… Green innovations have important network characteristics… Green innovations require especially large investments (or involve a large component of basic research, or have great inertia)… Outcomes of energy research are highly uncertain.[13]

What Nordhaus calls qualifications are frequently called market imperfections or barriers. Weyant starts with the R&D imperfection.

> This lack of "appropriability" of the benefits of one's own innovation creates a strong motivation for public support of R&D. Such support augments the extent to which simply increasing the price of clean energy relative to that of dirty energy induces innovation. A number of studies… estimate the social rate of return for innovation expenditures at approximately double the rate of return on private R&D expenditures… a close look at the energy sector industries and their potential entrants leads to the conclusion that they are industries where appropriability is difficult.[14]

However, Weyant elaborates on and goes well beyond the list of qualification offered by Nordhaus. He sees several additional supply-side problems.

> A close look at the energy industries and their potential entrants leads to the conclusion that… entry is risky and expensive, market organization is more likely to be oligopolistic than perfectly competitive, and information is strategically held and difficult to obtain…
>
> Further complicating matters, existing companies in energy-related industries --- those that produce energy, those that manufacture the equipment that produces, converts and uses energy, and those that distribute energy – can have substantial incentives to delay the introduction of new technologies. This can happen if their current technologies are more profitable than the new ones that might be (or have been) invented, or if they are in explicitly (oil and gas) or implicitly (electric generation equipment producers and automakers) oligopolistic structured, or if they are imperfectly regulated (electric and gas utilities). The incentive arises partly because the infrastructure for

[13] Nordhaus, 2011, pp. 672… 670-671.
[14] Weyent, 2011, pp. xx

producing, distributing, and promoting the industries' current products require large investments that have already been incurred.[15]

He also looks beyond the early phases of research and development on which Nordhaus focuses and notes market imperfections that may retard the adoption and diffusion of technologies on the demand-side.

> Imperfections in the market for energy-converting and energy-consuming equipment may be impeding the rate of diffusion of new technologies that are already economically competitive and welfare improving. This situation can result for several different types of market failure, including poor or asymmetric information available to purchasers, limits on individual's ability to make rational decisions because of time or skill constraints, principal-agent incongruities between building owners and building residents, and lack of financing opportunities.[16]

Roger Noll looks at the contrasting views and concludes that "Superficially, these messages conflict, but both are offered with sufficient caveats that, with minor amendments, these articles provide the right approach to near-term U.S. climate policy. Here I elaborate on the amendments that integrate these articles." [17] His amendments add important considerations that further complicate the terrain of policymaking.

> In principle, one could impose taxes on GHG emissions that correct for information imperfection, coordination failures, and market concentration, but the financial cost to consumers of using price instruments to overcome these problems plausibly could be too high to be politically feasible and higher than the cost of simply subsidizing green energy R&D…
>
> In the absence of targeted government interventions utilities are unlikely to make socially optimal investments in these technologies simply on the basis of an optimal emissions tax and a general R&D subsidy… potential entrants face a problem that, for the foreseeable future, the infrastructure is… a complement as well as a substitute… Thus, efficient diffusion of new green technologies requires involving the incumbents.[18]

Noll worries about the "misapplication of a valid principal," and cautions that "the key question is how much delay is the commercialization of new green technologies likely to occur even if Pigovian taxes and subsidies are imposed. The answer to this question remains unclear." While the available answer is not precise, the evidence suggests that the cost of inertia is quite large, and targeted approaches lower costs and speed the transition.[19]

- The general finding that the social return to R&D is twice as large as the private return appears to hold in the energy technology space.[20]
- Because of the magnitude of the change required, the macroeconomic impacts of policy take on great significance, with analysis of the macroeconomic savings from a

[15] Weyent, 2011, pp. 677.
[16] Weyent, 2011, pp. 675.
[17] Noll, 2011, pp. 683.
[18] Noll, 2011, pp. 685.
[19] Acemoglu, et al, 2012, pp. 132.
[20] Qui, 2012, Massetti and Nicita, 2010.

smoother, swifter transition yielding very substantial projected economic savings of at least 50%.[21]

- Estimates of the speed of innovation suggest a one to two decade delay in the introduction of new technologies, if targeted policies to accelerate the diffusion of innovation are not adopted.[22]
- Targeted financial incentives deliver three times as much monetary support for alternatives.[23]

The intense interest in the issues of barriers to change has broken through to the popular press, as demonstrated by a report by Ryan Avent, the Washington-based economic correspondent for the *Economist*. Reporting on "a great session on climate policy"[24] focused on "the environment and directed technical change" and Avent noted that it suggested

> [E]conomics is clearly moving beyond the carbon=tax alone position on climate change, which is a good thing. If the world is to reduce emissions, it needs technologies that are both green and cheap enough to be attractive to economically-stressed countries and people. And a carbon tax alone may not generate the necessary innovation… [T]he carbon externality isn't the only relevant externality in the mix. There is another important dynamic in which technological innovation draws on previous research, and so firms are more likely to continue on established innovation trajectories than to start new ones."[25]

About a year later, David Leonhardt (2013), an economic columnist for the New York Times discussed the practical implications of the growing recognition of the challenge of overcoming inertia and closing the "innovation gap."

> "Over the last several years, the governments of the United States, Europe and China have spent hundreds of billions of dollars on clean-energy research and deployment. And despite some high-profile flops, like ethanol and Solyndra, the investments seem to be succeeding more than they are failing… The successes make it possible at least to fathom a transition to clean energy that does not involve putting a price on carbon — either through a carbon tax or a cap-and-trade program that requires licenses for emissions… To describe the two approaches is to underline their political differences. A cap-and-trade program sets out to make the energy we use more expensive. An investment program aims to make alternative energy less expensive… Most scientists and economists, to be sure, think the best chance for success involves both strategies: if dirty energy remains as cheap as it is today, clean energy will have a much longer road to travel… Still, the clean-energy push has been successful enough to leave many climate advocates believing it is the single best hope… Governments have played a crucial role in financing many of the most important technological inventions of the past century. That's no coincidence: Basic research is often unprofitable. It involves too much failure, and an inventor typically captures only a tiny slice of the profits that flow from a discovery. Although government officials make mistakes when choosing among nascent technologies, one success can outweigh many failures."[26]

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[21] Grubb Chapuis and Duong, 1995, p. 428,
[22] Dechezlepetre, et al., 2011.
[23] Nordhaus, Shellenberger and Trembath, 2012, calculate that that targeted subsidies yield approximately three times the incentive to invest in low carbon alternatives (compared to coal) as a general carbon tax.
[24] Avent, 2011.
[25] Avent, 2011.
[26] Leohhardt, 2013.

B. Empirical Evidence on the Importance of Market Barriers and Imperfections

Exhibit V-2 presents observations on the factors that can inhibit the transition to energy sources and usage that would reduce greenhouse gas emissions significantly. Exhibit A-IV-2 provides citations. They are presented in the categories of market barriers and imperfections we have used throughout this analysis. For purposes of this literature review, we have applied the same criteria used in the review of the recent efficiency gap literature. We limit the scope to the last ten years and include studies that are empirical or review empirical studies. We see strong parallels between the empirical findings in the analysis of the response to climate change and the efficiency gap analysis.

Exhibit V-2: Market Barriers and Imperfection in Climate Change Analysis

Traditional Economics & Industrial Organization

Externalities
Knowledge Externalities that are not captured by markets, e
Research and Development (20, 22, 23, 48, D), a, b
Importance of learning by searching (27, 31, 38, E), c
Deployment: Importance of learning by doing (27, 10, 31, 38, B), c
Economics of Scale/returns to scale (6, 38, 41, 47, G), d
Localization (24, 38, 45, H))

Market Structure:
Cost Structures: Long investment cycles, increasing returns to scale, network effects (8, 28, 33, 498 I)
Challenge of creating new markets: Undifferentiated product (20, 23, 28, 42, J)
Entry Barriers: Capital Cost, access to network (20, 41, 47 48, K)
Lack of competition hinders innovation (41, 48, L)
Inertia:
Cost of Inertia (1, 14, 28, M)
Importance of inertia/stock of knowledge (9, 24, 37, 45, N)

New Institutional Economics

Endemic
Perverse incentives: in allocation of fuel price volatility (20, 50, O), carbon tax level and permanence (21, 30, 40, 44, P) g
Asymmetric information (21, 48, Q)
Shot-term view, h, i

Transaction Cost
Uncertainty: as a cause of underinvestment (8, 21, 26, 43, 47, R)
Fuel price volatility, carbon tax level and permanence (fuel price volatility, carbon tax level and permanence (20, 33, S)
High risk premia on new technologies (28, T)
Information: Value of information (2, 22, U)
Sunk costs and embedded infrastructure (21, 48, V)
Incomplete markets f

Political Power
Power of incumbents to hinder alternatives (20, 45, ZA)
Monopolistic structures and lack of competition (24, 39 41, 46, 47, ZB)
Importance of institutional support for Alternatives (22, 30, ZC)

Behavioral Economics

Behavior
Sluggish demand response (20, 23, W)
Agency (18, 8, X)
Risk Aversion (6, Y)
Calculation (17, 47, Z)

Effective Policy RESPONSES
Public goods (24, 49, ZC)
Institution Building (22, 30, 49, ZE)
Research and Development (5, 10, 20, 23, 25, 26, 28, 32, 35, 37, 47, ZF)
Capital subsidies Adders, premium prices (6, 41, ZG)
Obligations/Consenting (25, 28, 35, 47, M, (ZH)
Standards (8, 22, ZI)
Feed in Tariffs (28, 41, 45, 47, ZJ)
Merit order (20, 21, ZK)

Evidence on the ineffectiveness of price/ tax as policy
Price Insufficiency (4, 11, 15, 20, 19, 25, 29, 35, 41, 47, 48 A)
Tax: Difficulty of setting and sustaining "optimal" levels (20, 19, 47, B)
Tradable permits do not increase innovation (5, 36, C)

Sources: See Appendix C, Exhibit A-V-2

One primary theme is that the knowledge externality, or innovation gap, is a true externality that is reinforced by important characteristics of the energy market and policy context. Many of the benefits of alternative generation technology resources or the processes by which their costs would be reduced – e.g. learning by doing, network effects – are externalities themselves, which means the private sector will underinvest. [27]

A second major theme is that dislodging a dominant technology requires overcoming a great deal of physical and institutional inertia that has built up over decades. New technologies face significant barriers to entry that are compounded by the existence of entrenched incumbents. Thus, the inertia that supports the dominant incumbent technology is a central factor. A third major theme is market structural barriers to innovation. While the market power problem of dominant incumbents receives a great deal of attention,[28] given the desire to rely on competition and markets, the other market structural problems not associated with market power are equally important. Indeed, since competitive markets would be afflicted by these problems, they are actually a stronger basis to justify public policy to overcome inertia.[29]

Inertia is the result of several sets of market imperfection – market and institutional factors including market structure, endemic, behavioral and transaction costs issues. Some of the market imperfections exacerbate the problem of underinvestment in knowledge creation, but their impact on inertia is paramount. A long period in which fossil fuels were dominant and created a large market makes it the focal point of resources, and investment and will be the focal point of innovative activity. The existing skill sets and economic infrastructure costs reinforce the power of inertia.[30] Moreover, Gross, et al., 2012, point out that the incumbent fossil fuels were the winners, in part, because they were picked in the past and have been favored with policy advantages over a long period of time. The fact that the incumbent technologies have been and continue to be the beneficiaries of subsidies, is more than just a plea for "fairness," however, it reflects the fact that energy markets need these interventions to achieve important social goals, particularly when inertia must be overcome.[31] The ability of dominant incumbents to implement practices and promote policies that magnify the barriers to entry can compound the difficulty of entry if monopolistic

[27] Gross, et al., 2012, p. 18; Massetti and Nicita, 2010, p. 1The presence of market failures in the R&D sector, as emphasized by Griliches, is confirmed by the evidence, virtually found in all studies, that the social rate of return on R&D expenditure is higher than the corresponding private rate; estimates of the marginal social rate of return on R&D range between 30 and 50 percent and of private return between 7 and 15 percent… When it comes to technologies for carbon emissions reduction, the difference between private and social rate of return to R&D investment arises from a double externality; the presence of both environmental and knowledge externalities. First, without a price on carbon that equates the global and the private cost of emitting GHGs, all low emissions technologies are relatively disadvantaged and the level of investment is therefore sub-optimal. Second, the private return to investment in R&D is lower than the social return of investment due to the incomplete appropriability of knowledge creation, thus pushing further away investment for the socially optimal level.

[28] Gross, et al, 2012; Nicolli and Vona, 2012,

[29] Jamasb and Kohler, 2007, p. 9, Information technology and pharmaceuticals, for example, are both characterized by high degrees of innovation, with rapid technological change financed by private investment amounting typically to 10-20% of sector turnover. This is in dramatic contrast with power generation, where a small number of fundamentals technologies have dominated for almost a century and private sector RD&D has fallen sharply with privatization of energy industries to the point where it is uner 0.4% of turnover.

[30] Gross, et a;l, 2012, p.18.

[31] Gross, et al., p.18, The phenomenon of "learning by doing", whereby costs for technologies reduces as experience is gained from deployment of the technology creates lock-in. It also creates better, cheaper technologies. The incumbent fossil and nuclear forms of generation have had many decades of technical refinement through experience which have driven their costs down to low levels relatife to new, renewable technologies. In part, this was financed by considerable public subsidy… The very same effects that created locik-in to high carbon systems offer the potential to decrease the coss and improve the commercial/consumer attractiveness of new forms of low carbon energy.

bottlenecks are allowed to hamper access to the network, like incumbent control of access to the grid or dispatch. [32]

Since the alternative technologies are at a disadvantage in terms of development and the ability to attract resources, just raising the cost of the dominant fuels does not overcome the inertia and actually allows the gap between the incumbent and alternative technologies to persist or even grow.

The inertia can be compounded by several other factors including monopolistic distortions in the incumbent market, a lack of substitutability between the alternatives and limited spillovers from innovation in the incumbent technology. With an exhaustible resource, the problem can be particularly acute, as a tendency to underestimate the long term consequences of continuing dependence on it are not fully reflected in current decision making. Long lead times, increasing returns to scale and network effects make entry difficult (if not impossible).[33] The undifferentiated nature of the product makes it hard for new entrants to secure a foothold (niche) from which to build scale and learn-by doing.[34] Price volatility and other sources of uncertainty reduce the incentive to invest.[35] One of the most important additional sources of uncertainty beyond price is the uncertainty about the commitment to and sustainability of high carbon taxes needed to make alternatives attractive. [36] One of the causes of this uncertainty about policy commitment is the uneven social and geographic impact of high carbon taxes and the concern about high impact industries.[37]

The allocation of fuel price risk creates a disincentive to innovation.[38] The fact that the problem occurs in both regulated and deregulated markets suggests it is an endemic problem. Merit order dispatch and single price auctions set the market clearing price at the highest variable cost needed to clear the market. In regulated systems, fuel price risk for the marginal generator is shifted to ratepayers with adjustment clauses. In market systems, the risk is transferred to consumers and magnified, as noted early because all generators are paid the market clearing price. The marginal generator is shielded from risk. Combining the price setting function with the fact that marginal generators tend to have low capital costs, tends to insulate these generators from the risk of price volatility, which is shifted to consumers and alternative suppliers. Alternative generators, who have

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[32] Walz, 2007, Walz Scleich and Ragwitz, 2011.

[33] Kahlkuhl, Edenhoffer and Lessmann, 2012.

[34] Kalkuhl, Edenhofer and Lessmann, 2012, p. 10, The energy sector is highly vulnerable to lock-in because electricity is an almost perfect substitute for consumers. In contast, many innovations in the manufacturing or entertainment electronics sector provide a new product different from existing ones(e/g/ flat screens vs. CRT monitor). The low substitutability implies a high niched demand and, thus, provokes ongoing learning-by-doing although considerable spillovers exist and market prices are distorted.

[35] Cian and Massimo, 2011, p. 123, Uncertainty and irreversibility are two features of climate change that contribute to shape the decision making process. Technology cost uncertainty can depress the incentive to ivest. The risk of underinvestment is even more severe considering that energy infrastructure has a slow turnover. Capital irreversibility and uncertainty heighten the risk of locking into existing fossil-fuel-based technologies. Additional investment are sunk costs that increase the opportunity cost of acting now… The result is reinforced when uncertain costs have a large variance, showing that investments decrease with risk.

[36] Gross, et al, 2012, p. 16.

[37] Walsz, 16.

[60] Gross, Blyth and Heponstall, 2012, p. 802.The first conclusion is that policymaking in the energy area needs new tools of analysis that can deal with the market risks associated with policy design… In particular, policymakers need to be mindful of the role of revenue risk as well as cost risk in the business case for investment.

high capital costs and low operating costs and do not set the market clearing price, also bear the burden of fuel price risk.[39]

Consumers respond sluggishly to price increases, so the shifting of the risk of price volatility onto the consumers does not have the hoped for effect in stimulating demand for alternative resources.[40] Energy consuming durable have long lives and consumers frequently do not make the purchase decision. The agents who make the purchase decisions and consumers are first cost sensitive and have difficulty projecting energy prices and quantities to make lifecycle cost calculations.[41] The demand–side does not receive the attention commensurate with its importance as a source of market failure or its potential impact on the transition to a decarbonized sector.[42]

The set of factors that underlies the inertia that would retard the response to climate change are market barriers and imperfections that are similar to the set of factors that underlie the "efficiency gap." The debate among economists grappling with the analysis of climate change replicates and parallels the efficiency gap debate. The conceptual and empirical analysis of climate change adds a great deal of evidence to reinforce the conclusions about the barriers and imperfections that affect energy markets.

[39] Gross, et al,, 2012, pp. 13-14.
[40] Walz, 2011, Elder 2010; Jamasb and Kohler,2007,p. 8-9.
[41] Greene, 2010.
[42] Eilson, et al., 2012,

APPENDIX
ANNOTATED VERSIONS OF EXHIBITS

EXHIBIT A-II-2: MARKET BARRIERS TO ENERGY EFFICIENCY

Barriers[1]	Market Failures	Transaction Cost[2]	Behavioral factors[16]
Misplaced incentives	Externalities	Sunk costs[3]	Custom[17]
Agency[4]	Mis-pricing[20]	Lifetime[5]	Values[18] & Commitment[19]
Capital Illiquidity[8]	Public Goods[22]	Risk[6] & Uncertainty[7]	Social group & status[21]
Bundling	Basic research[23]	Asymmetric Info.[9]	Psychological Prospect[24]
Multi-attribute	Information	Imperfect Info.[10]	Ability to process info[27]
Gold Plating[11]	(Learning by Doing)[25]	Availability	Bounded rationality[26]
Inseparability[13]	Imperfect Competition/	Cost[12]	
Regulation	Market Power[28]	Accuracy	
Price Distortion[14]			
Chain of Barriers			
Disaggregated Mkt.[15]			

William H. Golove and Joseph H. Eto, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency;*

1) Six market barriers were initially identified: 1) misplaced incentives, 2) lack of access to financing, 3) flaws in market structure, 4) mis-pricing imposed by regulation, 5) decision influenced by custom, and 6) lack of information or misinformation. Subsequently a seventh barrier, referred to as "gold plating," was added to the taxonomy (p.9).

2) Neo-classical economics generally relies on the assumption of frictionless transactions in which no costs are associated with the transaction itself. In other words, the costs of such activities as collecting and analyzing information; negotiating with potential suppliers, partners, and customers; and assuming risk are assumed to be nonexistent or insignificant. This assumption has been increasingly challenged in recent years. The insights developed through these challenges represent an important new way to evaluate aspects of various market failures (especially those associated with imperfect information). Transaction cost economics examines the implications of evidence suggesting that transaction costs are not insignificant but, in fact, constitute a primary explanation for the particular form taken by many economic institutions and contractual relations (p. 22).

3) Transaction cost economics also offers support for claims that the illiquidity of certain investments leads to higher interest rates being required by investors in those investments (p. 23).

4) Misplaced, or split, incentives are transactions or exchanges where the economic benefits of energy conservation do not accrue to the person who is trying to conserve (p. 9).

5) Thus, as the rated lifetime of equipment increases, the uncertainty and the value of future benefits will be discounted significantly. The irreversibility of most energy efficiency investments is said to increase the cost of such investments because secondary markets do not exist or are not well-developed for most types of efficient equipment. This argument contends that illiquidity results in an option value to delaying investment in energy efficiency, which multiplies the necessary return from such investments (p. 16)

6) If a consumer wishes to purchase an energy-efficient piece of equipment, its efficiency should reduce the risk to the lender (by improving the borrower's net cash flow, one component of credit-worthiness5) and should, but does not, reduce the interest rate, according to the proponents of the theory of market barriers. (p.10). Potential investors, it is argued, will increase their discount rates to account for this uncertainty or risk because they are unable to diversify it away. The capital asset pricing model (CAPM) is invoked to make this point (p. 16).

7) Perfect information includes knowledge of the future, including, for example, future energy prices. Because the future is unknowable, uncertainty and risk are imposed on many transactions. The extent to which these unresolvable uncertainties affect the value of energy efficiency is one of the central questions in the market barriers debate. Of course, inability to predict the future is not unique to energy service markets. What is unique is the inability to diversify the risks associated with future uncertainty to the same extent that is available in other markets (p. 20).

8) In practice, we observe that some potential borrowers, for example low-income individuals and small business owners, are frequently unable to borrow at any price as the result of their economic status or "credit-worthiness." This lack of access to capital inhibits investments in energy efficiency by these classes of consumers (p. 10).

9) Finally, Williamson (1985) argues that the key issue surrounding information is not its public goods character, but rather its asymmetric distribution combined with the tendency of those who have it to use it opportunistically (p. 23).

10) [K]nowledge of current and future prices, technological options and developments, and all other factors that might influence the economics of a particular investment. Economists acknowledge that these conditions are frequently not and in some cases can never be met. A series of information market failures have been identified as inhibiting investments in energy efficiency: (1) the lack of information, (2) the cost of information, (3) the accuracy of information, and (4) the ability to use or act upon information (p. 20).

11) The notion of "gold plating" emerged from research suggesting that energy efficiency is frequently coupled with other costly features and is not available separately (p.11).

12) Even when information is potentially available, it frequently is expensive to acquire, requiring time, money or both (p. 20).

13) Inseparability of features refers specifically to cases where availability is inhibited by technological limitations. There may be direct tradeoffs between energy efficiency and other desirable features of a product. In contrast to gold plating where the consumer must purchase more features than are desired, the inseparability of features demands purchases of lower levels of features than desired. (p.12)

14) The regulation barrier referred to mis-pricing energy forms (such as electricity and natural gas) whose price was set administratively by regulatory bodies (p. 11).

15) On the cost-side of the equation, the critics contend that, among other things, information and search costs have typically been ignored or underestimated in engineering/economic analyses. Time and/or money may be spent: acquiring new information (search costs), installing new equipment, training operators and maintenance technicians, or supporting increased maintenance that may be associated with the energy efficient

equipment (p.16). [T]he class, itself, consists of a distribution of consumers: some could economically purchase additional efficiency, while others will find the new level of efficiency is not cost effective (p. 13).

16) Discounted cash-flow, cost-benefit, and social welfare analyses use price as the complete measure of value although in very different ways; behavioral scientists, on the other hand, have argued that a number of "noneconomic" variables contribute significantly to consumer decision making (p. 17).
17) [C]ustom and information have evolved significantly during the market barrier debate (p. 11).
18) In the language of (economic) utility theory, the profitability of energy efficiency investments is but one attribute consumers evaluate in making the investment. The value placed on these other attributes may, in some cases, outweigh the importance of the economic return on investment (p. 19).
19) [P]sychological considerations such as commitment and motivation play a key role in consumer decisions about energy efficiency investments (p. 17).
20) Externalities refer to costs or benefits associated with a particular economic activity or transaction that do not accrue to the participants in the activity (p. 18).
21) Other factors, such as membership in social groups, status considerations, and expressions of personal values play key roles in consumer decision-making (p.17). In order for a market to function effectively, all parties to an exchange or transaction must have equal bargaining power. In the event of unequal bargaining positions, we would expect that self-interest would lead to the exploitation of bargaining advantages (p. 19).
22) Public goods are said to represent a market failure. It has been generally acknowledged by economists and efficiency advocates that public good market failures affect the energy services market. (p. 19) [T]he creation of information is limited because information has public good qualities. That is, there may be limits to the creator's ability to capture the full benefits of the sale or transfer of information, in part because of the low cost of subsequent reproduction and distribution of the information, thus reducing the incentive to create information that might otherwise have significant value (p. 20).
23) Investment in basic research in believed to be subject to this shortcoming; because the information created as a result of such research may not be protected by patent or other property right, the producer of the information may be unable to capture the value of his/her creation (p. 19).
24) Important theoretical refinements to this concept, known as prospect theory, have been developed by Tversky and Kahneman (1981, 1986). This theory contends that individuals do not make decisions by maximizing prospective utility, but rather in terms of difference from an initial reference point. In addition, it is argued that individuals value equal gains and losses from this reference point differently, weighing losses more heavily than gains (p.21).
25) The information created by the adoption of a new technology by a given firm also has the characteristics of a public good. To the extent that this information is known by competitors, the risk associated with the subsequent adoption of this same technology may be reduced, yet the value inherent in this reduced risk cannot be captured by its creator (p. 19).
26) This work is consistent with the notion of bounded rationality in economic theory. In contrast to the standard economic assumption that all decision makers are perfectly informed and have the absolute intention and ability to make decisions that maximize their own welfare, bounded rationality emphasizes limitations to rational decision making that are imposed by constraints on a decision maker's attention, resources, and ability to process information. It assumes that economic actors intend to be rational, but are only able to exercise their rationality to a limited extent (p.21).
27) Finally, individuals and firms are limited in their ability to use — store, retrieve, and analyze — information. Given the quantity and complexity of information pertinent to energy efficiency investment decisions, this condition has received much consideration in the market barriers debate (p. 20).
28) This barrier suggests that certain powerful firms may be able to inhibit the introduction by competitors of energy-efficient, cost-effective products (p. 10).

EXHIBIT A-II-3: MARKET AND BEHAVIORAL FAILURES RELEVANT TO ENERGY EFFICIENCY

Societal Failures

- Energy Market Failures
  - Environmental Externalities[1]
  - Energy Security
- Innovation market failures
  - Research and development spillovers[2]
  - Learning-by-doing spillovers[3]
  - Learning-by-using[4]

Structural Failures

- Capital Market Failures
  - Liquidity constraints[5]
  - Information problems[6]
    - Lack of information[7]
    - Asymmetric info. >
      - Adverse selection[8]
    - Principal-agent problems[9]
    - Average-cost electricity pricing[10]

Potential Behavioral Failures[11]

- Prospect theory[12]
- Bounded rationality[13]
- Heuristic decision making[14]
- Information[15]

1) Externalities: the common theme in energy market failures is that energy prices do not reflect the true marginal social cost of energy consumption, either through environmental externalities, average cost pricing, or national security (9).

2) R&D spillovers may lead to underinvestment in energy-efficient technology innovation due to the public good nature of knowledge, whereby individual firms are unable to fully capture the benefits from their innovation efforts, which instead accrue partly to other firms and consumers (11).

3) Learning-by-doing (LBD) refers to the empirical observation that as cumulative production of new technologies increases, the cost of production tends to decline as the firm learns from experience how to reduce its costs (Arrow 1962). LBD may be associated with a market failure if the learning creates knowledge that spills over to other firms in the industry, lowering the costs for others without compensation.

4) Positive externalities associated with learning-by-using can exist where the adopter of a new energy-efficient product creates knowledge about the product through its use, and others freely benefit from the information generated about the existence, characteristics, and performance of the product (12).

5) Capital: Some purchasers of equipment may choose the less energy-efficient product due to lack of access to credit, resulting in underinvestment in energy efficiency and reflected in an implicit discount rate that is above typical market levels (13).

6) Information: Specific information problems cited include consumers' lack of information about the availability of and savings from energy-efficient products, asymmetric information, principal-agent or split-incentive problems, and externalities associated with learning-by-using (11).

7) Lack of information and asymmetric information are often given as reasons why consumers systematically underinvest in energy efficiency. The idea is that consumers often lack sufficient information about the difference in future operating costs between more-efficient and less-efficient goods necessary to make proper investment decisions (11).

8) Asymmetric information, where one party involved in a transaction has more information than another, may lead to adverse selection (11).

9) Agency: The principal-agent or split-incentive problem describes a situation where one party (the agent), such as a builder or landlord, decides the level of energy efficiency in a building, while a second party (the principal), such as the purchaser or tenant, pays the energy bills. When the principal has incomplete information about the energy efficiency of the building, the first party may not be able to recoup the costs of energy efficiency investments in the purchase price or rent charged for the building. The agent will then underinvest in energy efficiency relative to the social optimum, creating a market failure (12).

10) Prices faced by consumers in electricity markets also may not reflect marginal social costs due to the common use of average-cost pricing under utility regulation. Average-cost pricing could lead to under- or overuse of electricity relative to the economic optimum (10).

11) Systematic biases in consumer decision making that lead to underinvestment in energy efficiency relative to the cost-minimizing level are also often included among market barriers. (8); The behavioral economics literature has drawn attention to several systematic biases in consumer decision making that may be relevant to decisions regarding investment in energy efficiency. Similar insights can be gained from the literature on energy decision-making in psychology and sociology. The evidence that consumer decisions are not always perfectly rational is quite strong, beginning with Tversky and Kahneman's research indicating that both sophisticated and naïve respondents will consistently violate axioms of rational choice in certain situations (15).

12) The welfare change from gains and losses is evaluated with respect to a reference point, usually the status quo. In addition, consumers are risk averse with respect to gains and risk seeking with respect to losses, so that the welfare change is much greater from a loss than from an expected gain of the same magnitude (Kahneman and Tversky 1979). This can lead to loss aversion, anchoring, status quo bias, and other anomalous behavior (16).

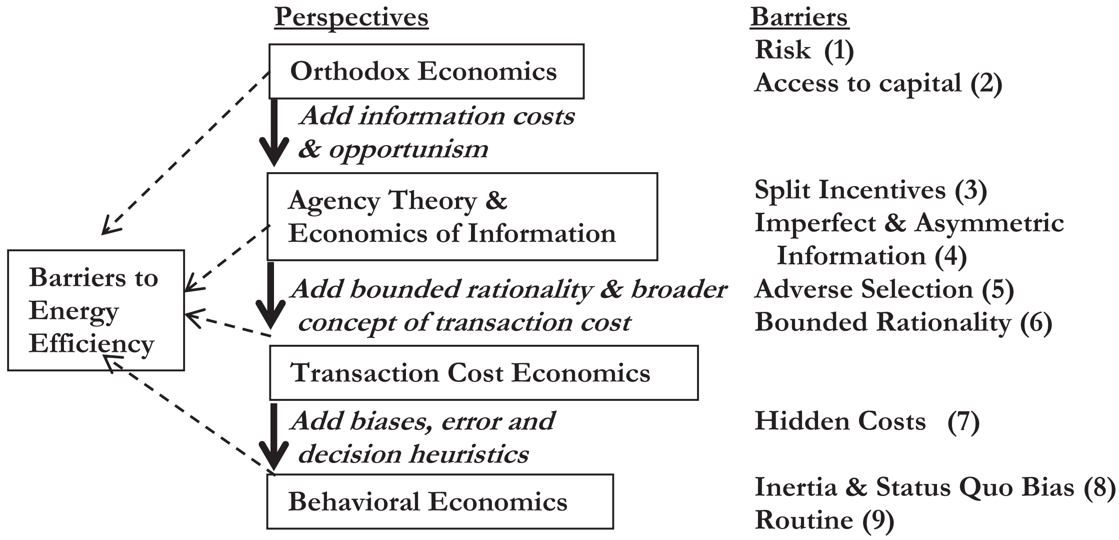
13) Bounded rationality suggests that consumers are rational, but face cognitive constraints in processing information that lead to deviation from rationality in certain circumstances (16); Assessing the future savings requires forming expectations of future energy prices, changes in other operating costs related to the energy use (e.g., pollution charges), intensity of use of the product, and equipment lifetime. Comparing these expected future cash flows to the initial cost requires discounting the future cash flows to present values (3).

14) Heuristic decision-making is related closely to bounded rationality and encompasses a variety of decision strategies that differ in some critical way from conventional utility maximization in order to reduce the cognitive burden of decision-making. Tversky (1972) develops the theory of elimination-by-aspects," wherein consumers use a sequential decision making process where they first narrow their full choice set to a smaller set by eliminating products that do not have some desired feature or aspect (e.g., cost above a certain level), and then they optimize among the smaller choice set, possibly after eliminating further products. (16) For example, for decisions regarding energy-efficient investments consumers tend to use a simple payback measure where the total investment cost is divided by the future savings calculated by using the energy price today, rather than the price at the time of the savings— effectively ignoring future increases in real fuel prices (p. 17). The salience effect may influence energy efficiency decisions, potentially contributing to an overemphasis on the initial cost of an energy-efficient purchase, leading to an underinvestment in energy efficiency. This may be related to evidence suggesting that decision makers are more sensitive to up-front investment costs than energy operating costs, although this evidence may also be the result of inappropriate measures of expectations of future energy use and prices (17).

15) Alternatively, information problems may occur when there are behavioral failures, so that consumers are not appropriately taking future reductions in energy costs into account in making present investments in energy efficiency (12).

Source: Kenneth Gillingham, Richard G. Newell, and Karen Palmer, *Energy Efficiency Economics and Policy* (Resources for the Future, April 2009)

EXHIBIT A-II-4: BARRIERS TO INDUSTRIAL ENERGY EFFICIENCY



Steve Sorrell, Alexandra Mallett & Sheridan Nye. *Barriers to industrial energy efficiency, A literature review,* United Nations Industrial Development Organization, Vienna, 2011, Figure 3.1 & Section 3.

(1) Risk: The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because energy efficiency investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages short time horizons.

(2) Access to capital: If an organization has insufficient capital through internal funds, and has difficulty raising additional funds through borrowing or share issues, energy efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term incentives of energy management staff.

(3) Split incentives: Energy efficiency opportunities are likely to be foregone if actors cannot appropriate the benefits of the investment. Wide applicability… Landlord-tenant problems may arise in the industrial, public and commercial sectors through the leasing of buildings and office space. The purchaser may have a strong incentive to minimise capital costs, but may not be accountable for running costs….maintenance staff may have a strong incentive to minimize capital costs and/or to get failed equipment working again as soon as possible, but may have no incentive to minimise running costs. If individual departments within an organization are not accountable for their energy use they will have no incentive to improve energy efficiency.

(4) Imperfect information: Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed. In some cases, imperfect information may lead to inefficient products driving efficient products out of the market. Information on: the level and pattern of current energy consumption and comparison with relevant benchmarks; specific opportunities, such as the retrofit of thermal insulation; and the energy consumption of new and refurbished buildings, process plant and purchased equipment, allowing choice between efficient and inefficient options.
Asymmetric information exists where the supplier of a good or service holds relevant information, but is unable or unwilling to transfer this information to prospective buyers.

(5) Asymmetric information may lead to the adverse selection of energy inefficient goods.

(6) Bounded rationality: Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in economic models. As a consequence, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentive consumers do not attempt to maximise their utility or producers their profits.

(7) Hidden costs Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies may overestimate energy efficiency potential. Examples of hidden costs include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing and applying information.
General overhead costs of energy management: employing specialist people (e.g., energy manager); energy information systems (including: gathering of energy consumption data; maintaining sub metering systems; analysing data and correcting for influencing factors; identifying faults; etc.); energy auditing;
Costs involved in individual technology decisions: i) identifying opportunities; ii) detailed investigation and design; iii) formal investment appraisal; formal procedures for seeking approval of capital expenditures; specification and tendering for capital works to manufacturers and contractors additional staff costs for maintenance; replacement, early retirement, or retraining of staff; disruptions and inconvenience;
Loss of utility associated with energy efficient: problems with safety, noise, working conditions, service quality etc. (e.g., lighting levels); extra maintenance, lower reliability,

(8) Inertia and the status quo bias: Routines can be surprisingly persistent and entrenched. … This type of problem has been labeled *inertia* within the energy efficiency literature and identified as a relevant explanatory variable for the efficiency gap

(9) Routines as a response to bounded rationality the use of formal capital budgeting tools within investment decision-making. Other types of rules and routines which may impact on energy efficiency include: operating procedures (such as leaving equipment running or on standby); safety and maintenance procedures; relationships with particular suppliers; design criteria; specification and procurement procedures; equipment replacement routines and so on.

EXHIBIT A-II-7: RECENT EMPIRICAL EVIDENCE ON MARKET FAILURES, BARRIERS AND IMPERFECTIONS

TRADITIONAL ECONOMICS & INDUSTRIAL ORGANIZATION

Externalities
- Public goods[1] & Bads[2]
- Basic research
- Network effects
- Information as a public good
- Learning-by-doing & Using[9]

Industry Structure
- Imperfect Competition
  - Concentration[13]
  - Barriers to entry
  - Scale[18]
  - Switching costs[20]
- Technology[23]
  - R&D
  - Investment[25]
- Marketing
  - Bundling: Multi-attribute[26]
  - Substitutes[27]
- Cost-Price
  - Limit impact of price[29]
    - Fragmented Mkt.[30]
    - Limited payback[31]

Regulation
- Price[34]
  - Infrequent
  - Aggregate, Avg.-cost[35]
- Lack of commitment[36]

NEW INSTITUTIONAL ECONOMICS

Endemic Imperfections
- Asymmetric Info[3].
- Agency[5]
- Adverse selection[6]
- Perverse incentives
- Lack of capital[10]

TRANSACTION COST
- Search and Information
- Imperfect info[14]
  - Availability[16]
  - Accuracy
  - Search cost[21]
- Bargaining
  - Risk & Uncertainty[24]
  - Liability
- Enforcement
- Sunk costs
- Hidden cost[28]

Political Power
- Power of incumbents to hinder alternatives
- Monopolistic structures and lack of competition
- Importance of institutional support for Alternatives[32]
- Inertia[33]

BEHAVIORAL ECONOMICS

Motivation & Values
- Non-economic[4]

Influence & Commitment
- Custom[7]
- Social group & status[8]

Perception
- Bounded Vision/Attention[11]
- Prospect[12]

Calculation.
- Bounded rationality[15]
- Limited ability to process info[17]
- Heuristic decision making[19]
- Discounting difficulty[22]

Citations

1. Macroeconomic: Edelstein and Killian, 2009, p. 13, [T]he cumulative effects on real consumption associated with energy price shocks are quantitatively important. We showed that the responses of real consumption aggregates are too large to reflect the effects of unanticipated change in discretionary income alone. Our analysis suggests that the excess response can be attributed to shifts in precautionary savings and to changes in the operating costs of energy using durables.
2. Committee On Health, Environmental, And Other External Costs And Benefits Of Energy Production And Consumption, 2011, p. I, D]espite energy's many benefits, most of which are reflected in energy market prices, the production, distribution, and use of energy also cause negative effects. Beneficial or negative effects that are not reflected in energy market prices are termed "external effects" by economists. In the absence of government intervention, external effects associated with energy production and use are generally not taken into account in decision making. When prices do not adequately reflect them, the monetary value assigned to benefits or adverse effects (referred to as damages) are "hidden" in the sense that government and other decision makers, such as electric utility managers, may not recognize the full costs of their actions. When market failures like this occur, there may be a case for government interventions in the form of regulations, taxes, fees, tradable permits, or other instruments that will motivate such recognition.
3. UNIDO, 2011, p. 19, Asymmetric information exists where the supplier of a good or service holds relevant information, but is unable or unwilling to transfer this information to prospective buyers. The extent to which asymmetric information leads to market failure will depend upon the nature of the good or service…. In contrast to

energy commodities, energy efficiency may only be considered a search good when the energy consumption of a product is clearly and unambiguously labelled and when the performance in use is insensitive to installation, operation and maintenance conditions. But for many goods, the information on energy consumption may be missing, ambiguous or hidden, and the search costs will be relatively high. In the absence of standardised performance measures or rating schemes, it may be difficult to compare the performance of competing products. Taken together, these features tend to make energy efficiency closer to a *credence good* and hence more subject to market failure. Thus, to the extent that energy supply and energy efficiency represent different means of delivering the same level of energy service, the latter is likely to be disadvantaged relative to the former. The result is likely to be overconsumption of energy and under-consumption of energy efficiency.

4. Alcott, 2011, p. 1, Results show that beliefs are both highly noisy, consistent with imperfect information and bounded computational capacity, and systematically biased in manner symptomatic of "MPG illusion;" Alcott and Wozny, 2010.
5. Davis, xxx, p. 1; Extensive analysis of U.S. and global markets support the conclusion that this is an important impediment to greater energy efficiency of consumer durables. "The results show that, controlling for household income and other household characteristics, renters are significantly less likely to have energy efficient refrigerators, clothes washers and dishwashers."
6. UNIDO, 2011, p. 19, In some circumstances, asymmetric information in energy service markets may lead to the adverse selection of energy inefficient goods. Take housing as an example. In a perfect market, the resale value of a house would reflect the discounted value of energy efficiency investments. But asymmetric information at the point of sale tends to prevent this. Buyers have difficulty in recognising the potential energy savings and rarely account for this when making a price offer. Estate agents have greater resources than buyers, but similarly neglect energy efficiency when valuing a house. Since the operating costs of a house affect the ability of a borrower to repay the mortgage, they should be reflected in mortgage qualifications. Again, they are not. In all cases, one party (e.g., the builder or the seller) may have the relevant information, but transaction costs impede the transfer of that information to the potential purchaser. The result may be to discourage house builders from constructing energy efficient houses, or to discourage homeowners from making energy efficiency improvements since they will not be able to capture the additional costs in the sale price.
7. Ozaki and Sevastyanove, 2009.
8. Claudy and O'Dricoll, 2008, p. 11, "A growing body of literature around energy conservation contends that investment into energy efficiency measure is often motivated by "conviction" rather than "economics." Behavioral factors, including attitudes and values, explain a greater amount of variation in proenvironmental behaviour and provide valuable insights for policy makers and analysts."
9. Deroches, 2011, p. 1, Costs and prices generally fall in relations to cumulative production, a phenomenon known as experience and modeled as a fairly robust empirical experience curve… These experience curves… incorporated into recent energy conservation standards… impact on the national modeling can be significant, often increasing the net present value of potential standard levels… These results imply that past energy conservation standards analyses may have undervalued the economic benefits of potential standard levels.
10. UNIDO, 2011, p. iii, If an organization has insufficient capital through internal funds, and has difficulty raising additional funds through borrowing or share issues, energy efficient investments may be prevented from going ahead. Investment could also be inhibited by internal capital budgeting procedures, investment appraisal rules and the short-term incentives of energy management staff.
11. Alcott, 2009, p. 1. "I provide evidence to suggest that at least some of this effect is because consumers' attention is malleable and non-durable." UNIDO, pp. viii, Owing to constraints on time, attention, and the ability to process information, individuals do not make decisions in the manner assumed in economic models. As a consequence, they may neglect opportunities for improving energy efficiency, even when given good information and appropriate incentive consumers do not attempt to maximise their utility or producers their profits.
12. Sardiano, 2007, p. 1417, Decision making process to invest in energy efficiency improvement, like other investments, is a function of the behavior of individual or of various actors within the industrial firm. In this context, managerial attitudes toward energy conservation are also important factors… [E]nergy efficiency measures are often not overlooked by management because it is not a core business activity and it is thus not worth much attention.
13. Blumstein, 2013, p. 5, [T]he existence of market power dampens the responsiveness of suppliers of goods or services to consumer demand, as actors in a monopolistic or oligopolistic setting can more or less set prices and quality attributes.
14. Atari, et. al., 2010, p. 1. For a sample of 15 activities, participants underestimated energy use and savings by a factor of 2.8 on average, with small overestimates for lower-energy activities and large, underestimates for high-energy activities." Jessoe and Rapson, 2013, p. 34, "These results confirm the practical importance of one of economics' most ubiquitous assumptions – that decision makers have perfect information. Indeed, the absence of perfect information is likely to cause substantial efficiency loses both in this setting and others in which quantity is also

infrequently or partially observed by decision makers." Consumers Union, 2012, p. 8, "this suggests that many consumers are misinformed about the program requirements.

15. Green, German and Delucchi, 2009, p. 203; "The uncertainty/loss aversion model of consumers' fuel economy decision making implies that consumers will undervalue expected future fuel savings to roughly the same degree as manufacturers' perception that consumers demand short payback periods."
16. UNIDO, 2011, p. iii, Lack of information on energy efficiency opportunities may lead to cost-effective opportunities being missed. In some cases, imperfect information may lead to inefficient products driving efficient products out of the market. Information on: the level and pattern of current energy consumption and comparison with relevant benchmarks; specific opportunities, such as the retrofit of thermal insulation; and the energy consumption of new and refurbished buildings, process plant and purchased equipment, allowing choice between efficient and inefficient options.
17. Atari, et. al., 2010, p. 1. For a sample of 15 activities, participants underestimated energy use and savings by a factor of 2.8 on average, with small overestimates for lower-energy activities and large, underestimates for high-energy activities."
18. Montvalo, 2007, p. S10, Due to the size of investment and longevity or production processes it is very likely that the diffusion of new processes will occur in an incremental way.
19. Ito, 2010, p. 1, Evidence from laboratory experiments suggests that consumers facing such price schedules may respond to average price as a heuristic. I empirically test this prediction using field data.
20. Sardianou, 2007, p. 1419, Our empirical results also confirm that organizational constraints and human related factors can be thought of as barriers in incorporating the energy saving technology in incorporating the energy saving technology in the existing production process.
21. Sardianou, 2007, p. 1419, Having limited information with regard to energy conservation opportunities and their profitability is considered an obstacle…. Other possible barriers include lack of documentation of energy data.
22. Kurani and Turrentine, 2004, p. 1, One effect of limited knowledge is that when consumers buy a vehicle, they do not have the basic building blocks of knowledge to make an economically rational decision. When offered a choice to pay more for better fuel economy, most households were unable to estimate potential savings, particularly over periods of time greater than one month. In the absence of such calculations, many households were overly optimistic about potential fuel savings, wanting and thinking they could recover an investment of several thousand dollars in a couple of years.
23. Montvalo, 2007, p. A10, Finally, firms face the challenge of technological risk. The gains promised by new technologies have yet to materialize, a situation that contrasts strongly with the perceived reliability of the current, familiar operating process. In the literature on technology management it has been established that adoption or development of new production processes implies the capacity to integrate new knowledge and large organizational change.
24. UNIDO, 2011, p. iii, The short paybacks required for energy efficiency investments may represent a rational response to risk. This could be because energy efficiency investments represent a higher technical or financial risk than other types of investment, or that business and market uncertainty encourages short time horizons.
25. Montvalo, 2007, p. s10, Closely related to these technological opportunities are the firm and sector level capabilities to actually adopt new technologies. It has been reported that insufficient availability of expertise in clear production (eco-design) the current training and clean technology capacity building at the sector level and the insufficient understanding and experience in cleaner production project development and implementation, play a role in the adoption of new cleaner production processes. These factors can be expected to become even more critical at the level of small- and medium sized enterprises..
26. Gabaix and Laibson, 2005, p. 1; "We show that information shrouding flourishes even in highly competitive markets, even in markets with costless advertising, and even when the shrouding generation allocational inefficiencies." Hosain and Morgan, Brown, Hossain and Morgan
27. Sallee, 2012, "The possibility of rational inattention has two key implications. First, if consumers rationally ignore energy efficiency, this could explain the energy paradox. In equilibrium, firms will underprovide energy efficiency if consumers ignore it. If true, this would qualitatively change the interpretation of empirical work on the energy paradox. Most empirical work tests for the rationality of consumer choice across goods that are actually sold in the market. If rational inattention leads to an inefficiency set of *product offerings* (emphasis added), consumer might choose rationally among goods in equilibrium but a paradox still exists. Second, if consumers are rationally inattentive to energy efficiency, this could provide direct justification for regulatory standards and "no tech policies, such as the Energy Star Label System." Green, German and Delucchi, 2009, p. 203; This suggests that increasing fuel prices may not be the most effective policy for increasing the application of technologies to increase passenger and light truck fuel economy. This view is supported by the similar levels of technology applied to U.S. and European passenger cars in the 1990s, despite fuel prices roughly three times higher in Europe. It is also circumstantially supported by

the adoption by governments around the world of regulatory standard for light-duty vehicle fuel economy and carbon dioxide emissions.

28. UNIDO, 2011, p. iii, Hidden costs Engineering-economic analyses may fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with them. As a consequence, the studies may overestimate energy efficiency potential. Examples of hidden costs include overhead costs for management, disruptions to production, staff replacement and training, and the costs associated with gathering, analysing and applying information. General overhead costs of energy management: employing specialist people (e.g., energy manager); energy information systems (including: gathering of energy consumption data; maintaining sub metering systems; analysing data and correcting for influencing factors; identifying faults; etc.); energy auditing; Costs involved in individual technology decisions: i) identifying opportunities; ii) detailed investigation and design; iii) formal investment appraisal; formal procedures for seeking approval of capital expenditures; specification and tendering for capital works to manufacturers and contractors additional staff costs for maintenance; replacement, early retirement, or retraining of staff; disruptions and inconvenience; Loss of utility associated with energy efficient: problems with safety, noise, working conditions, service quality etc. (e.g., lighting levels); extra maintenance, lower reliability.
29. Li, Timmins and von Haefen, 2009, "we are able to decompose the effects of gasoline prices on the evolution of the vehicle fleet into changes arising from the inflow of new vehicles and the outflow of used vehicles. We find that gasoline prices have statistically significant effects on both channels, but their combined effects results in only modest impacts on fleet fuel economy. The short-run and long-run elasticities of fleet fuel economy with respect to gasoline prices are estimated at 0.o22 and 0.204in 2005. "
30. Committee to Assess Fuel Economy, 2010, p. 2, The [Medium and Heavy Duty] truck world is more complicated. There are literally thousands of different configurations of vehicle including bucket trucks, pickup trucks, garbage trucks, delivery vehicles, and long-haul trailers. Their duty cycles vary greatly… the party responsible for the final truck configuration is often not well defined.; Lutzenheiser, et al., (2001, cited in Blumstein, 2013), p. viii, The commercial building "industry" is in fact a series of linked industries arrayed along a "value chain" or "value stream" where each loosely coupled link contributes value to a material building in process. Each link, while aware of the other links in the process, is a somewhat separate social world with its own logic, language, actors, interests, and regulatory demands. For the most part "upstream" actors constrain the choices and actions of "downstream" actors.
31. Sardianou, 2007, p. 1419, The lack of access to capital (76%) and the slow rate of return (74%) of energy savings investments are categorized as barriers.
32. UNIDO, 2011, p. iii, Routines as a response to bounded rationality the use of formal capital budgeting tools within investment decision-making. Other types of rules and routines which may impact on energy efficiency include: operating procedures (such as leaving equipment running or on standby); safety and maintenance procedures; relationships with particular suppliers; design criteria; specification and procurement procedures; equipment replacement routines and so on.
33. Montvalo, 2007, A11, organization capabilities refer to the firm's endowments and capabilities to carry out innovation… When the knowledge is not present in the firm adoption will depend on the firm's capacity to overcome shill lock-in, and to unlearn and acquire new skills. UNIDO, Inertia and the status quo bias: Routines can be surprisingly persistent and entrenched. … This type of problem has been labeled inertia within the energy efficiency literature and identified as a relevant explanatory variable for the efficiency gap.
34. Sardianou, 2007, p. 1419, Uncertainty about future energy prices (62%) is also characterized as a barrier [leading] to the postponement of energy efficiency measures.
35. Ito, 2010, p. 1, I find strong evidence that consumers respond to average price rather than marginal or expected marginal price.
36. UNIDO, 2011, p. 67, The government does not give financial incentives to improve energy efficiency, Lack of coordination between different government agencies, Lack of enforcement of government regulations, There is a lack of coordination between external organizations; Sardianou, 2007, p. 1402, [B]ureaucratic procedure to get government financial support is a barrier to energy efficiency improvements for the majority (80%) of industries.

EXHIBIT A-V-2: MARKET BARRIERS AND IMPERFECTION IN CLIMATE CHANGE ANALYSIS

TRADITIONAL ECONOMICS & INDUSTRIAL ORGANIZATION

EXTERNALITIES

Knowledge Externalities that are not captured by markets, e
Research and Development (20, 22, 23, 48, D), a, b
Importance of learning by searching (27, 31, 38, E), c
Deployment: Importance of learning by doing (27, 10, 31, 38, B), c
Economics of Scale/returns to scale (6, 38, 41, 47, G), d
Localization (24, 38, 45, H))

MARKET STRUCTURE:

Cost Structures: Long investment cycles, increasing returns to scale, network effects (8, 28, 33, 498 I)
Challenge of creating new markets: Undifferentiated product (20, 23, 28, 42, J)
Entry Barriers: Capital Cost, access to network (20, 41, 47 48, K)
Lack of competition hinders innovation (41, 48, L)

INERTIA:

Cost of Inertia (1, 14, 28, M)
Importance of inertia/stock of knowledge (9, 24, 37, 45, N)

NEW INSTITUTIONAL ECONOMICS

ENDEMIC

Perverse incentives: in allocation of fuel price volatility (20, 50, O), carbon tax level and permanence (21, 30, 40, 44, P) g
Asymmetric information (21, 48, Q)
Shot-term view, h, i

TRANSACTION COST

Uncertainty: as a cause of underinvestment (8, 21, 26, 43, 47, R)
Fuel price volatility, carbon tax level and permanence (fuel price volatility, carbon tax level and permanence (20, 33, S)
High risk premia on new technologies (28, T)
Information: Value of information (2, 22, U)
Sunk costs and embedded infrastructure (21, 48, V)
Incomplete markets f

POLITICAL POWER

Power of incumbents to hinder alternatives (20, 45, ZA)
Monopolistic structures and lack of competition (24, 39 41, 46, 47, ZB)
Importance of institutional support for Alternatives (22, 30, ZC)

BEHAVIORAL ECONOMICS

BEHAVIOR

Sluggish demand response (20, 23, W)
Agency (18, 8, X)
Risk Aversion (6, Y)
Calculation (17, 47, Z)

EFFECTIVE POLICY RESPONSES

Public goods (24, 49, ZC)
Institution Building (22, 30, 49, ZE)
Research and Development (5, 10, 20, 23, 25, 26, 28, 32, 35, 37, 47, ZF)
Capital subsidies Adders, premium prices (6, 41, ZG)
Obligations/Consenting (25, 28, 35, 47, M, (ZH)
Standards (8, 22, ZI)
Feed in Tariffs (28, 41, 45, 47, ZJ)
Merit order (20, 21, ZK)

EVIDENCE ON THE INEFFECTIVENESS OF PRICE/ TAX AS POLICY

Price Insufficiency (4, 11, 15, 20, 19, 25, 29, 35, 41, 47, 48 A)
Tax: Difficulty of setting and sustaining "optimal" levels (20, 19, 47, B)
Tradable permits do not increase innovation (5, 36, C)

Lower case letters (a) Raymond J. Kopp and William A Pizer, *Assessing U.S. Climate Policy Options* (Washington, D.C.: November 2007);
Upper case letters (A) keyed to the following climate change sources:

1 Acemoglu, Daron, et al., 2012, *"The Environment and Dedicated Technical Change," American Economic Review, 102(1*)
2 Baker, Erin and Yiming Peng, "The Value of Better Information on Technology R&D Programs in Response to -Climate change," *Environmental Model Assessment,* 17
3 Braun, Franked G., Jens Schmidt-Emcee and Petra Zloczyisti, 2010, Innovative *Activity in Wind and Solar Technology: Empirical Evidence on Knowledge Spillovers Using Patent Data,* Growth and Sustainability Polies for Europe, June
4 Breakthrough Journal, *Yale Environment 360 Debate, 2011*
5 Calel, Raphael and Antoine Dechexlepetre, *Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market,* 2012
6 Chu, Shan-Ying, 2012, "Innovation and Diffusion of Wind Power in Taiwan," *Journal of Global Business Management*
7 DB Climate Change Advisor, Paying for Renewable Energy: TLC at the Right Price, December 2009
8 De Cian, Enrica and Tavoni Massimo, "Mitigation Portfolio and Policy Instruments When Hedging Again Climate Policy and Technological Uncertainty," *Environmental Model Assessment,* 2012:17.
9 Dechezleperte, Antoine, et al., 2011, *Climate change & Directed Innovation: Evidence from the Auto Industry, London School of Economics and Political Science*
10 Ek, Kristina and Patrik Soderholm, "Technology Learning in the Present of Public R&D: The Case of European Wind Power," *Ecological Economics,* 2010: 69
11 Fuss, Sabine and Jana Szolgayova, "Fuel Price and Technological Uncertainty in a real Option Model for electricity Planning," *Applied Energy,* 2010: 87
12 Fuss, Sabine et al., "Investment Under Market and Climate Policy Uncertainty, "Applied Energy, 85:208
13 Fuss, Sabine, et al. "Impact of Climate Policy Uncertainty on the Adoption of Electricity Generating Technologies, Energy Policy, 37: 2009

14 Gerlagh, Reyer, Snorre Kverndokk, and Knut Einar Rosendhal, 2009, "Optimal Timing of Climate change Policy: Interaction between Carbon Taxes and Innovation Externalities," *Environmental Resource Economics,* 43
15 Gerlgh, Reyer, "Measuring the Value of Induced Technological Change," *Energy Policy,* 35:2007
16 Greene, David, "Uncertainty, Loss Aversion, and Markets for Efficiency," *Energy Economics,* 2011:11
17 Greene, David, L., John German and Mark A. Deluchhi, "Fuel Economy: The Ace for Market Failure," in Daniel Sperling and James S. Cannon (eds.), *Reducing Climate Impacts in the Transportation Sector,* 2009
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19 Grimaudi, André and Gilles Laffrougue, *Climate Change Mitigation Policies: Are R&D Subsidies Preferable to a Carbon Tax,* Tolouse School of Economics, November 21, 2008
20 Gross, Robert, et al., *On Picking Winners: The Need for Targeted Support for Renewable Energy,* Imperial College London, October 2012
21 Gross, Robert, William Blyth and Philip Heponstall, "Risks, Revenues and Investment in Electricity Generation: why Policy Needs to Look Beyond costs," *Energy Economics,* 2010: 32.
22 Hoebach, Jon, "Determinants of Environmental Innovations -- New Evidence from German Panel Data Source," Research Policy, 37:2008
23 Jamasb, Tooraj, and Jonathan Kohler, *Learning Curves for Energy Technology: A Critical Assessment,* University of Cambridge, October 2007
24 Johnstone, Nick and Ivan Hascic, *Directing Technological Change while Reducing the Risk of (not) Picking Winners: The Case of Renewable Energy,* November 2010.
25 Johnstone, Nick, Ivan Hascic and David Popp, 2008, *Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts,* National Bureau of Economic Research, January 2008.
26 Jouvet, Pierre-Andre, Elodie Le Cadre and Caroline Orset, "Irreversible Investment, Uncertainty, and Ambiguity: The Case of Bioenergy Sector," *Energy Economics,* 2012:34.
27 Kahouli Brahmi, Sondes, "Technological Learning in Energy-Environment-Economy Modeling: A Survey," *Energy Policy,* 2008:36.
28 Kalkuhl, Matthias, Ottmar Edenhofer, Kai Lessmann, "Learning or Lock-in: Optimal Technology Policies to Support Mitigation, *Resource and Energy Economics,* 2012:34
29 Kemp, Rene and Serena Pontoglio, "The Innovation Effects of Environmental Policy Instruments -- A Typical Case of the Blind Men and the Elephant?," Ecological Economics, 72: 2011
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31 Lindman, Asa and Patrik Soderholm, "Wind Power Learning Rates: a conceptual Review and Meta-Analysis," *Energy Economics,* 2012:34.
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46 Walz, R., "the Role of Regulation for Sustainable Infrastructure Innovation: the Case of Wind energy," *International Journal of Public Policy,* 2007
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49 Weyant, John P., "Accelerating the Development and Diffusion of New Energy Technologies: Beyond the Valley of Death," Energy Economics, 33: 2011
49 Wilson, Charlie, et al., "Marginalization of End Use Technologies in Energy Innovation for Climate Protection
50 Zorlu, Pelin, et al., Risk Managing Power Sector Decarbonization in the UK, E3G, October 2012

a) Public Goods:, Many technologies have competing or multiplicative (rather than additive) impact. The most compelling economics typically reside with the first abatement options in the analytical sequence. Pursuing energy efficiency in electric power, for example, has the potential to reduce the number of new coal-fired power plants needed (p. xx); The mismatch between near-term technology

investment and long-term needs is likely to be even greater in a situation where the magnitude of desired GHG reductions can be expected to increase over time. If more stringent emissions constraint will eventually be needed, society will benefit from near-term R&D to lower the cost of achieving those reductions in the future. Similarly, rationales for public support of technology demonstration projects tend to point to the… inability of private firms to capture the rewards for rewards for designing and constructing first-of-a-kind facilities. (p. 120)

(b) R&D tends to be underprovided in a competitive markets because its benefits are often widely distributed and difficult to capture by individual firms…. economics literature on R&D points to the difficulty firms face in capturing all the benefits from their investments in innovation, which tend to spill over to other technology producers and users.. (pp. 118-120); In addition, by virtue of its critical role in the higher education system, public R&D funding will continue to be important in training researchers and engineers with the skill necessary to work in either the public or private sector to product GHG-reducing technology innovations (p. 120)… Generic public funding for research tends to receive widespread support based on significant positive spillovers that are often associated with the generation of new knowledge. (p. 136).

(c) "Another potential rationale involves spillover effects that he process of so-called "learning-by-doing" – a term that describes the tendency for production costs to fall as manufacturers gain production experience."(p. 136)

(e) Network Effects: Network effects provide a motivation for deployment policies aimed at improving coordination and planning – and where appropriate, developing compatibility standards – in situations that involve interrelated technologies, particularly within large integrated systems (for example, energy productions, transmission, and distribution networks). Setting standards in a network context may reduce excess inertia (for example, the so-called chicken-and-egg problems with alternative fuel vehicles), while simultaneously reducing search and coordination costs, but standard scan also reduce the diversity of technology options offered and may impede innovation over time. (p. 137)

(e) Similarly, rationales for public support of technology demonstration projects tend to point to the large expense; (p.120).

(f) Similarly, rationales for public support of technology demonstration projects tend to point to the large expense; high degree of technical, market and regulatory risk; and inability of private firms to capture the rewards for rewards for designing and constructing first-of-a-kind facilities. (p. 120)

(g) Finally, incomplete insurance markets may provide a rationale for liability protection or other policies for certain technology options (for example, long-term CO2 storage). (p. 137)

(h) Regulatory risk: Similarly, rationales for public support of technology demonstration projects tend to point to the… high degree of technical, market and regulatory risk. The problem of private-sector under investment in technology innovation may be exacerbated in the climate context where the energy assets involved are often very-long lives and where the incentives for bringing forward new technology rest heavily on domestic and international policies rather than natural market forces. Put another way, the development of climate-friendly technologies has little market value absent a sustained, credible government commitment to reducing GHG emissions. (p. 120)

g) The mismatch between near-term technology investment and long-term needs is likely to be even greater in situation where the magnitude of desired GHG reductions can be expected to increase over time. If more stringent emissions constraint will eventually be needed, society will benefit from near-term R&D to lower the cost of achieving those reductions in the future. (p. 120)."

h) Finally, incomplete insurance markets may provide a rationale for liability protection or other policies for certain technology options (for example, long-term CO2 storage, (p.137)."

i) The problem of private-sector under investment in technology innovation may be exacerbated in the climate context where the energy assets involved are often very-long lives and where the incentives for bringing forward new technology rest heavily on domestic and international policies rather than natural market forces… "Put another way, the development of climate-friendly technologies has little market value absent a sustained, credible government commitment to reducing GHG emissions (p.12).

A Walz, Schleich and Ragwitz, 2011, p. 16, Power prices, however, are not found to drive patent activity. Hence power prices alone would likely not be sufficient to spur innovation activities in wind and arguably also other, currently less cost-efficient renewable technologies.

B The stability and long term vision of policy target setting are important policy style variables, which contribute to the legitimacy of technology and provide guidance of search…

C Calel and Dechezloprete, 2012, p. 1. "[M]ore refined estimates that combine matching methods with different-in-difference provide evidence that the EU ETS has not impacted the direction of technological change. This finding appears to be robust to a number of stability and sensitivity checks. While we cannot completely rule out the possibility that the EU ETS has impacted only large companies for which suitable unregulated comparators cannot be found, our findings suggest that the EU ETS so far has had at best a very limited impact on low-carbon technological change.

D Massetti and Nicita, 2010, p. 1The presence of market failures in the R&D sector, as emphasized by Griliches, is confirmed by the evidence, virtually found in all studies, that the social rate of return on R&D expenditure is higher than the corresponding private rate; estimates of the marginal social rate of return on R&D range between 30 and 50 percent and of private return between 7 and 15 percent… When it comes to technologies for carbon emissions reduction, the difference between private and social rate of return to R&D investment arises from a double externality; the presence of both environmental and knowledge externalities. First, without a price on carbon that equates the global and the private cost of emitting GHGs, all low emissions technologies are relatively disadvantaged and the level of investment is therefore sub-optimal. Second, the private return to investment in R&D is lower than the social return of investment due to the incomplete appropriability of knowledge creation, thus pushing further away investment for the socially optimal level.

E Massetti and Nicita, 2010, p. 17, We find that a [carbon] stabilization policy together with an R&D policy targeted at the only energy sector is significantly less costly than the stabilization policy alone. We find that energy R&D does not crowd-out non-energy R&D, and thanks to intersectoral spillovers, the policy induced increase in energy efficiency R&D spills over to the non-energy sector, contributing to knowledge accumulation and the reduction of knowledge externalities.

F Gross, et al., p.18, The phenomenon of "learning by doing", whereby costs for technologies reduces as experience is gained from deployment of the technology creates lock-in. It also creates better, cheaper technologies. The incumbent fossil and nuclear forms of generation have had many decades of technical refinement through experience which have driven their costs down to low levels relative to new, renewable technologies. In part, this was financed by considerable public subsidy… The very same effects that created lock-in to high carbon systems offer the potential to decrease the costs and improve the commercial/consumer attractiveness of new forms of low carbon energy.

G Qui and Anadon, pp. 782, The size of the wind farm is another significant factor in all specifications… indicate that a doubling in wind farm size could lead to price reductions of about 8.9%.

H Qui and Anadon, pp. 782, Localization rate is a significant factor in all specifications… indicate that a doubling of localization rate was associated with reductions in wind electricity price ranging from 10.9% to 11,4%.

I Cian and Massimo, 2011, p. 123, Uncertainty and irreversibility are two features of climate change that contribute to shape the decision making process. Technology cost uncertainty can depress the incentive to invest. The risk of underinvestment is even more severe considering that energy infrastructure has a slow turnover. Capital irreversibility and uncertainty heighten the risk of locking into existing fossil-fuel-based technologies. Additional investments are sunk costs that increase the opportunity cost of acting now… The result is reinforced when uncertain costs have a large variance, showing that investments decrease with risk. Jamasb and Nicita, (2007, p 8) R&D activity can be subject to three main types of market failure namely indivisibility, uncertainty and externalities.

J J. Kalkuhl, Edenhofer and Lessmann, 2012, p. 10, The energy sector is highly vulnerable to lock-in because electricity is an almost perfect substitute for consumers. In contrast, many innovations in the manufacturing or entertainment electronics sector provide a new product different from existing ones (e/g/ flat screens vs. CRT monitor). The low substitutability implies a high niched demand and, thus, provokes ongoing learning-by-doing although considerable spillovers exist and market prices are distorted.

K K. Gross, et al. 2012, p. 18, In the energy sector, such "network externalities" rise for example in the physical structures of large scale high voltage alternating current (AC) power grids themselves (themselves a reminders of early energy planners' desire to locate power stations close to the source of coal) which now provides a cost advantage to large scale centralized station over distributed alternatives.

L Gross, et al., 2012, p. 10, Either policymakers around the world are blind to the logic of economic theory, or there are factors that overwhelm or undermine the theoretical Pigouvian considerations. The rest of this paper discusses the considerations t

M Grimaud and Lafforgue, 2008, p. 1…20,The main results of the paper are the following: i) both a carbon tax and a green research subsidy contribute to climate change mitigation; ii) R&D subsidies have a large impact on the consumption, and then social welfare, as compared to the carbon tax alone; IV) those subsidies allow to spare the earlier generations who are, on the other hand, penalized by a carbon tax….In a second-best world, a carbon tax used alone leads to a higher social cost (with respect to first-best) than a research policy alone;

N Jamasb and Kohler, 2007, p. 9, Information technology and pharmaceuticals, for example, are both characterized by high degrees of innovation, with rapid technological change financed by private investment amounting typically to 10-20% of sector turnover. This is in dramatic contrast with power generation, where a small number of fundamentals technologies have dominated for almost a century and private sector RD&D has fallen sharply with privatization of energy industries to the point where it is under 0.4% of turnover.

O Gross, et al., 2012, p. 14, Capital intensive, zero fuel cost power stations like wind farms, need to cover their long run average costs—namely the cost of capital. They can neither actively affect/set marginal power prices nor respond to power price changes, except to curtail output, which does not save costs (as there are no fuel cost to save), but does lose revenue. However, carbon prices only affect the marginal price of fuel and power. We should therefore expect that an emissions trading scheme will encourage fuel switching from coal to gas, and efficiency first and renewable energy (or indeed nuclear) investment last. This is exactly what we have seen in reality.

P Reuter, et al., 2012, p. 253, If there is uncertainty about the future development of feed-in-tariffs, much higher levels will be needed to make renewable investment attractive for energy companies.

Q Gross, 210, p. 802, "A range of factors that relate to the amount and quality of information about technology costs and risks available to policymakers and market participants are relevant when considering incentives and investment in new technologies: Policymakers may have relatively poor information about costs for emerging technologies. 'Appraisal optimism' (where technology/project developers under estimate the cost of unproven technology/systems) is a common feature in the development of new technologies. When providing cost data to policymakers technology developers or equipment suppliers may also have incentives to up or play down costs and potential according to circumstances. Where new or unproven technologies are being utilized for the first time, information about costs may be limited for all concerned... There may be an 'option value' to potential investors in waiting (delaying investment) where there is poor information and high levels of technology and market risk. The first conclusion is that policymaking in the energy area needs new tools of analysis that can deal with the market risks associated with policy design… In particular, policymakers need to be mindful of the role of revenue risk as well as cost risk in the business case for investment.

R Fuss and Szolgayosva, 2010, p.2938, We find that the uncertainty associated with the technological progress of renewable energy technologies leads to a postponement of investment. Even the simultaneous inclusion of stochastic fossil fuel prices in the same model does not make renewable energy competitive compared to fossil-fuel-fired technology in the short run based on the data used. This implies that policymakers have to intervene if renewable energy is supposed to get diffused more quickly. Otherwise, old fossil-fuel-fired equipment will be refurbished or replaced by fossil-fuel-fired capacity again, which enforces the lock-in of the current system into unsustainable electricity generation.

S Gross, et al., 2012, In short,, whilst carbon pricing can create conditions that make investment in wind more attractive, there are uncertainties associated with wholesale power prices, carbon permit prices, and future political decisions on carbon tax levels. These make wind investment more risky, which drives up the cost of capital investors require higher returns), and discourage investment.

T Gross, Blyth and Heponstall, 2012, p. 802.The first conclusion is that policymaking in the energy area needs new tools of analysis that can deal with the market risks associated with policy design… In particular, policymakers need to be mindful of the role of revenue risk as well as cost risk in the business case for investment.

U Horbach, 2007, p. 172, Environmental management tools help to reduce the information deficits to detect cost savings (especially material and energy savings) that are an important driving force of environmental innovation.

V Weyant, 2011, p. 677, The infrastructure for producing, distributing, and promoting the industries' current products require large investments that have already been incurred.

W Jamasb and Kohler, 2007, Thus, the 'market pull' forces reach deep into the innovation chain…This is in contrast with power generation, where a small number fundamental and private sector RD&D has fallen sharply with privatization of energy industries. technologies have dominated for almost a century and private RD&D has fallen sharply with privatization... In turn, market pull measures are devised to promote technical change by creating demand and developing the market for new technologies.

X Weyant, 2011, p. 675, The situation can develop from several different types of market failure, including poor or asymmetric information available to purchasers, limits on individual's ability to make rational decisions because of time or skill constraints, principle agent incongruities... and lack of financing opportunities.

Z Green, 2010, p. 6, The rational economic consumer considers fuel saving over the full life of a vehicle, discounting future fuel savings to present value. This requires the consumer to know how long the vehicle will remain in operation; he distances to be traveled in each future year, the reduction in the rate of fuel consumptions, and the future price of fuel…. The consumer must also estimate the fuel economy that will be achieved in real world driving based on the official estimate. Finally, the consumer must know how to make a discounted present value calculation, or must know how to obtain one… The utility-maximizing rational consumer has fixed preferences, possesses all complete and accurate information about all relevant alternatives, and has all the cognitive skills necessary to evaluate the alternatives. These are strict requirements indeed….

ZA Nicolli and Vona, p. 1, Our empirical results are consistent with predictions of political-economy models of environmental policies as lobbying, income and to a less extent, inequality have expected effects on policy. The brown lobbying power, proxied by entry barriers in the energy sector, has negative influence on the policy indicators even when taking into account endogeneity in its effect. The results are also robust to dynamic model specifications and to the exclusion of groups of countries

ZB Weyant, 2011, p. 677, Further complicating matters, existing companies in energy-related industries --- those that produce energy, those that manufacture the equipment that produces, converts and uses energy, and those that distribute energy – can have substantial incentives to delay the introduction of new technologies. This can happen if their current technologies are more profitable than the new ones that might be (or have been) invented, or if they are in explicitly (oil and gas) or implicitly (electric generation equipment producers and automakers) oligopolistic structured, or if they are imperfectly regulated (electric and gas utilities). The incentive arises partly because the infrastructure for producing, distributing, and promoting the industries' current products require large investments that have already been incurred.

ZC Horbach, 2008, p. 172, An environmentally oriented research policy has not only to regard traditional instruments like the improvement of the technological capabilities of a firm but also the coordination with soft environmental policy instruments like the introduction of environmental management systems.

ZD Johnstone and Haccic, 2010, p.25 "Since innovating in storage technologies is an important complement to innovation in all intermittent renewable generating technologies such a strategy reduces the risk of (not) picking winners. Moreover, the technologies are at a relatively early stage of development, with greater need for support.

ZE Wilson, et al., p. 781, The institutions emphasized in our analytic framework are twofold: the propensity of entrepreneurs to invest in risky innovation activities with uncertain pay-offs; and shared expectation around an innovation's future trajectory. Other important and related institutions include law, markets and public policy. Public resources are invested directly into specific innovation stages, or are used to leverage private sector resources through regulatory or market incentives structured by public policy…. New technologies successfully diffuse as a function of their relative advantage over incumbent technologies. For energy technologies, this can be measured by the difference in cost and performance of energy service provision in terms of quality, versatility, environmental impact and so on. Many of these attributes of relative advantage can be shaped by public policy as well as the other elements of the innovation system.

ZF Walz, Schleich and Ragwitz, 2011, p. 5, The specific advantage of feed-in tariffs is seen in lower transaction costs and reduced risk perception for investors and innovators, which are extremely important especially for new entrants and for financial institutions.

ZH Walz, Schleich and Ragwitz, 2011, p. 16, Our econometric analyses also imply that the existence of targets for renewables/wind and a stable policy support environment are associated with higher patent activity.

ZI de Chien and Massimon, 2012, pp. 13…15, Against this evidence, regulation such as Emissions Performance Standards (EPS) that set a maximum threshold for the emission intensity of power generation in terms of grams of CO_2 per kilowatt hour could be justified as a way to reduce uncertainty exposure... [W]e have also pointed out that the optimal penetration of renewables is slow, even when facing a given deterministic carbon price.

ZG Rubbeike and Weiss, 2011, Including non-price-based variable increases the fit of the model… the coefficients for grants is positive and highly significant.

ZJ Gross, Blyth and Heptonstall, 2010, 802,The international evidence suggests that in most cases countries with fixed price schemes have been more successful at deploying renewables than those with trading scheme. Whilst the reasons for this are complex and varied it appears likely that investment r k plays an important role.

ZK Gross, Blyth and Heptonstall, 2010, 798,The result is that significant long-run fuel price uncertainty.. cannot usually be hedged through contractual arrangements. Long-run fuel price changes, like time of day rates, are mediated by the current market arrangements but remain fundamental to electricity prices.

EXHIBIT A-V-3: CAUSES OF CARBON LOCK-IN

<u>Business Innovation Risk – Cost Effectiveness and Fiscal Barriers</u> Technical risk Volatile Energy Prices Market risk High up-front costs <u>Transaction Costs</u> Inadequate workforce/infrastructure Misinformation Imperfect information Lack of specialized Inadequate validation	<u>Incumbent Support</u> Industry structure Inadequate supply chain Monopoly power <u>Policy Obstacles – Regulatory/Statutory barriers</u> Unfavorable policy environment Unfavorable regulation Uncertain Regulations Burdensome Permitting Uncertain/Unfavorable fiscal policy Misplaced incentives

Cost-Effectiveness Barriers

External Benefits and Costs: External benefits of GHG-reducing technologies that the owners of the technologies are unable to appropriate (e.g., GHG emission reductions from substitutes for high GWP gases and carbon sequestration).

External costs associated with technologies using fossil fuels (e.g., GHG emissions and health effects from small particles) making it difficult for higher priced, GHG-reducing technologies to compete.

High Costs: High up-front costs associated with the production and purchase of many low carbon technologies; high operations and maintenance costs typical of first-of-a-kind technologies; high cost of financing and limited access to credit especially by low-income households and small businesses.

Technical Risks: Risks associated with unproven technology when there is insufficient validation of technology performance. Confounded by high capital cost, high labor/operating cost, excessive downtime, lack of standardization, and lack of engineering, procurement and construction capacity, all of which create an environment of uncertainty.

Market Risks: Low demand typical of emerging technologies including lack of long-term product purchase agreements; uncertainties associated with the cost of a new product vis-à-vis its competitors and the possibility that a superior product could emerge; rising prices for product inputs including energy feedstocks; lack of indemnification.

Lack of Specialized Knowledge: Inadequate workforce competence; cost of developing a knowledge base for available workforce; inadequate reference knowledge for decision makers.

Fiscal Barriers

Unfavorable Fiscal Policy: Distortionary tax subsidies that favor conventional energy sources and high levels of energy consumption; fiscal policies that slow the pace of capital stock turnover; state and local variability in fiscal policies such as tax incentives and property tax policies. Also includes various unfavorable tariffs set by the public sector and utilities (e.g., import tariffs for ethanol and standby charges for distributed generators) as well as unfavorable electricity pricing policies and rate recovery mechanisms.

Fiscal Uncertainty Short-duration tax policies that lead to uncertain fiscal incentives, such as production tax credits; uncertain future costs for GHG emissions.

Regulatory Barriers

Unfavorable Regulatory Policies: Distortionary regulations that favor conventional energy sources and discourage technological innovation, including certain power plant regulations, rules impacting the use of combined heat and power, parts of the federal fuel economy standards for cars and trucks, and certain codes and standards regulating the buildings industry;

burdensome and underdeveloped regulations and permitting processes; poor land use planning that promotes sprawl.

Regulatory Uncertainty: Uncertainty about future regulations of greenhouse gases; uncertainty about the disposal of spent nuclear fuels; uncertain siting regulations for off-shore wind; lack of codes and standards; uncertainty regarding possible future GHG regulations.

Statutory Barriers

Unfavorable Statutory Policies: Lack of modern and enforceable building codes; state laws that prevent energy saving performance contracting.

Statutory Uncertainty: Uncertainty about future statutes including renewable and energy efficiency portfolio standards; unclear property rights relative to surface injection of CO2, subsurface ownership of CO2 and methane, and wind energy.

Intellectual Property Barriers

High Intellectual Property

Transaction Costs: High transaction costs for patent filing and enforcement, conflicting views of a patent's value, and systemic problems at the USPTO.

Anti-competitive Patent Practices Techniques such as patent warehousing, suppression, and blocking.

Weak International Patent Protection: Inconsistent or nonexistent patent protection in developing countries and emerging markets.

University, Industry, Government Perceptions: Conflicting goals of universities, national laboratories, and industry concerning CRADAs and technology commercialization.

Other Barriers

Incomplete and Imperfect Information: Lack of information about technology performance – especially trusted information; bundled benefits and decision-making complexities;

High cost of gathering and processing information; misinformation and myths; lack of sociotechnical learning; and lack of stakeholders and constituents.
Infrastructure Limitations: Inadequate critical infrastructure – including electric transmission capabilities and long-term nuclear fuel storage facilities; shortage of complementary technologies that encourage investment or broaden the market for GHG-reducing technologies;
insufficient supply and distribution channels; lack of O&M facilities and other supply chain shortfalls.
Industry Structure: Natural monopoly in utilities disenabling small-scale competition;
Industry fragmentation slowing technological change, complicating coordination, and
limiting investment capital.
Misplaced Incentives: Misplaced incentives when the buyer/owner is not the consumer/user (e.g., landlords and tenants in the rental market and speculative construction in the buildings industry) – also known as the principal-agent problem.
Policy Uncertainty: Uncertainty about future environmental and other policies; lack of leadership

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